Lessons from the Third International Mathematics and Science Study

A study commissioned by the Australian Government Department of Education, Science and Training

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Australian Council for Educational Research

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Executive Summary

TIMSS – the Third International Mathematics and Science Study – was a massive international project. Internationally, more than half a million students from over 30 000 classes in more than 15 000 schools in 45 countries participated. In Australia, the sample consisted of more than 29 000 students at three grade levels. This report is based on data obtained from the younger two cohorts: those at grade 4/5 (approximately 12 500 students) and those at grade 8/9 level (approximately 14 500 students). Its focus is on understanding the factors that influence achievement in mathematics and science.

Framework

The conceptual framework underlying TIMSS centres on four basic questions:

- what are students expected to learn?
- who delivers the curriculum?
- how is instruction organised?
- what have students learned?

In order to provide information about each of these, students, teachers and schools completed questionnaires. Together with the achievement tests, these questionnaires provide us with a range of variables with which to explore student achievement in mathematics and science.

The Report

Results for each population have been reported previously, however in each, separate analyses were conducted from the data for students, teachers and schools. However, outcomes of schooling are likely to be related to a range of factors operating at each of these levels and interacting in complex ways. In order to explore these interactions, multivariate and multilevel analyses are required. The focus of this book is on building the multilevel (or hierarchical) models needed to examine properly the independent effects of student background factors, teacher or classroom factors, and school factors, that play a part in students' achievement in mathematics and science. This is necessary due to the hierarchical nature of the data: students are clustered within classrooms and classrooms are clustered within schools. In Australia, data were collected for two mathematics classes in each school, allowing the development of a three-level model. Students were surveyed in intact mathematics classes. However in general they spread out rather more widely for science classes, and as a result of smaller numbers, the classroom and school data for science have had to be combined as a single level.

Previous Perspectives

A review of related studies produced ample evidence that a multitude of factors influence mathematics and science achievement. Large-scale studies in particular were reviewed, particularly those with a similar purpose to TIMSS – to identify factors pertaining to schooling that 'make a difference' as far as learning outcomes for students are concerned. Clusters of variables similar to those featured in TIMSS were a focus, as were those large-scale studies examining variables at different levels of the hierarchy of schooling. The consistent thread running through the studies reviewed is that student-level factors are the most powerful in accounting for achievement differences. Some studies successfully identified teacher or classroom-level factors as having an influence on achievement, but the effects of these factors were relatively small compared with the effects of student-level factors. The same was true for school-level factors. Nevertheless, using multilevel modelling techniques, some schools can be identified as having more ‘value-added’ effect than others, allowing factors to be identified that may be able to be manipulated to achieve better outcomes for students.

An overview of results from the Australian TIMSS reports provided information about which variables were related to mathematics and science achievement for the data which was being used for this study, in order to identify the variables that were likely to be useful in the secondary analyses. For primary school students (population) 1, the main findings from those reports were:

- achievement in mathematics and science is most strongly related to socioeconomic and sociocultural factors such as *status of parents’ occupation* and the *number of books in the home;*
- students from larger families and those who spoke a language other than English at home at least some of the time achieved lower scores in all areas than those from smaller families and those from families who only spoke English (although the relationships with achievement were not as strong as those for scoieconomic influences).

For junior secondary school students (population 2), the most important influence on achievement in mathematics and science was the educational level to which the student aspired. Again, socioeconomic and sociocultural factors such as mother’s or father’s occupation, mother’s or father’s education, number of books in the home and number of possessions in the home were all positively associated with achievement.

Another finding of note from the correlational analysis was that perceived importance of doing well in mathematics and science was important for the secondary school students but not for the primary students, particularly the importance of mathematics or science for getting a job or getting into a post-school course. It was, however, important for achievement for students to like mathematics and science, and to have confidence in their ability to do well, with those who found these subjects boring and those with the least confidence most likely to be those who were achieving at the lowest levels.

For both groups of students, the most significant negative correlations were between achievement and belief in external factors (such as good luck) as the source of success in mathematics and science.

Potential Influences

Multivariate analysis of the data was conducted to examine the independent effects of the variables on mathematics and science achievement. The overwhelming picture of the results of all four analyses is one of similarity rather than difference in the findings.

Student influences

Word knowledge, as a surrogate for developed verbal ability, was an overridingly strong predictor of achievement in both mathematics and science, at both grade levels. While this probably says something about the nature of the TIMSS tests, there is no doubt that modern approaches to teaching mathematics or science with a contextual basis mean that merely testing algorithms or abstract algebraic systems would be regarded as not useful. Thus, the current approaches to teaching and assessment mean that verbal skills and the ability to communicate one’s reasoning in constructed, written responses are essential to making progress at school in most subject areas, including mathematics and science.

The level of relationship found with socio-cultural variables in these analyses is similar to that which pervades the research literature in western societies. Those with greater access to resources, be it financial or cultural, such as number of books in the home, achieve at higher levels than those who do not, even holding constant developed verbal ability.

Teacher influences

Teachers play an important role in students' learning of mathematics and science, partly because of their pedagogical knowledge and partly because of their attitudes and beliefs about teaching their subject matter. Initial analyses of the teacher data found that the greatest proportion of both primary and secondary level teachers were aged between 40 and 49 years. At the primary level, almost three-quarters of the teachers in the TIMSS sample were female, while just under one-half of the mathematics and science teachers at secondary level were female. About 15 per cent of the primary teachers, and a little over one-quarter of the secondary mathematics and science teachers held postgraduate qualifications.

For the primary teachers, six underlying factors were derived from the items posed to teachers about teaching and learning their subject matter for underlying constructs:

- Problem-solving approach to teaching (ie responses to items about the frequency with which students are asked to explain their reasoning, work in small groups);
- Traditional approach to teaching (ie responses to items about the frequency that students practice computational skills, work together as a class with the teacher teaching);
- Importance of student understanding (ie responses to items about the teachers' perceptions about the importance of students understanding how mathematics is used, importance that students think creatively);
- Mathematics as a structured, real-world representation (ie responses to items about whether mathematics is primarily a practical and structured guide for addressing real situations);
- Mathematics as a set of rules and procedures (ie responses to items about whether mathematics should be learnt as sets of algorithms or rules that cover all possibilities); and
- Teaching as a profession (ie whether teachers believe that students and society appreciate their work, and whether they would change jobs if given the opportunity).

For the secondary school mathematics teachers, five underlying constructs were derived, matching those for the primary teachers other than factors 3 and 4 that were combined into a single factor. For the secondary level science teachers, five underlying constructs were also derived, again very similar to those already described for primary teachers.

School influences

Principals were asked to respond to a survey that asked about the location of the school, the number of students, and the school's climate, intellectual capital and provision of resources.

The largest problem in secondary schools was found to be with student lateness to school, which occurred on a daily basis in almost 60 per cent of schools, although only amongst small groups of students. Student absenteeism was also found to be a problem in secondary schools, with a little over 40 per cent of schools reporting that it was a problem on a daily basis, although again with only a small proportion of students. The largest problem in primary schools was with lateness, although this was a problem of a much smaller order than for secondary schools.

While there are clearly some relationships between some school climate variables with mathematics and science achievement, it is likely that there are complex interactions between these variables and those at the student level and the classroom level. As such, a better picture can be obtained by considering each group simultaneously as clusters of variables.

Findings

To eliminate problems caused by different grade levels, a common grade level was chosen for these analyses: Year 4 for primary schools and Year 8 for secondary schools. The clusters of variables that were entered into the models of mathematics achievement represented:

- Student background variables (sex, number of books in the home, family size, ethnicity, socioeconomic status);
- Student mediating variables (word knowledge score, student's attitude towards mathematics, student's perception of the importance of mathematics);
- Classroom composition variables (class-level mathematics attitude, class-level word knowledge score);
- Classroom teacher variables (age, sex, educational qualifications, years teaching, factor scores on the six [five for secondary students/teachers] underlying factors); and
- School level variables (school size, amount of time spent on mathematics, school location, and school average socioeconomic status).

To examine the effects of different variables on mathematics achievement, a model was built by successively adding blocks of variables. In the primary school sample, 70 per cent of the explained variance in mathematics achievement was associated with differences among students within classrooms, 12 per cent with differences between classrooms, and 18 per cent with differences between schools. In the secondary sample the corresponding proportions were 57 per cent, 32 per cent and 11 per cent. In other words, there were greater differences between schools at primary than secondary level, but at both levels most of the variation was among individual students (and a large proportion of that was explained by developed verbal ability).

Students

The expected influence of student social background (socioeconomic status, books in the home and family size) on achievement in both mathematics and science was found. However, this influence was much reduced when the Word Knowledge score was included in the analysis. In other words social background influences achievement both through its effect on developed ability (reflected in Word Knowledge) and through its direct effects. Lower socioeconomic status is associated with lower scores on the Word Knowledge test and this is in turn reflected in lower levels of achievement.

The analyses also showed a small but significant difference between males and females in mathematics achievement in population 1 but not in population 2. This appeared larger after allowance was made for differences in Word Knowledge scores. In other words females had higher scores on the Word Knowledge test than males but this was not reflected in their mathematics achievement in primary school, but in secondary school the opposite was apparent. Initially there was a gender difference but when allowance was made for Word Knowledge, this difference became non-significant. This means that males and females with similar levels of developed ability scored similarly on the mathematics test. In science the gap between males and females in achievement was wider than in mathematics, and evident at both primary and secondary school.

There was no effect of language background other than English on achievement in mathematics and only a very weak effect in science.

Having positive attitudes to mathematics or science was found to result in higher achievement in that area, even after allowing for the influence of developed ability. This was evident at both primary and secondary school level but was stronger at secondary school level. Although this is a student-level influence it has relevance for curriculum and teaching. It suggests that it is important to foster positive attitudes to mathematics and science if higher achievement outcomes are to be attained. An additional conclusion is that the influence of developed ability (word knowledge) is smaller at secondary level than primary school for mathematics, suggesting that mathematics is a more distinctive domain of achievement at this level of schooling and reflects school arrangements for more specialised teaching in that subject. The influence of developed ability was, however, stronger in science for secondary school than for primary school.

Schools and classrooms

School and classroom factors also influence mathematics achievement. At primary school level 30 per cent of the variation in achievement was associated with differences among schools or classrooms and at secondary school level the corresponding percentage was 43 per cent. For science the corresponding figures were 21 per cent at both primary and secondary school level. At both primary and secondary level the composition of classrooms (in terms of social background and developed ability) was an important influence on achievement. In the case of secondary schools, if the class was one with a high mean level of developed ability (higher class average Word Knowledge scores), mathematics and science achievement was higher. From a social learning perspective this is consistent with an interpretation that the resources that students bring to the classroom influence the learning that takes place and achievement. From a policy perspective it presents a dilemma: achievement can be enhanced for some but at the expense of others.

In the multilevel analyses it was not possible to detect any overall influences of differences in either teacher background or approaches to teaching mathematics. In part this may be because it is hard to capture the detail of what happens in classrooms from teachers' answers to survey questions. It may also result from the form of variable-focused analysis typically employed. In the more detailed studies of unusually effective (and ineffective) classrooms it was suggested that features of schools related to student management (less lateness, absence, misbehaviour) may be associated with higher levels of achievement. Those issues remain to be investigated further in more focused studies concerned with the clusters of classroom characteristics associated with different patterns of achievement.

States

State differences were also explored in a four-level multilevel analysis, with state as a fourth level. This was only possible for the five larger states. The analysis showed clearly that while there were state differences, differences within states were far greater than those between states, particularly after taking into account prior verbal ability and socioeconomic status. There are, however, particular factors that appear to affect student achievement in mathematics across all states. These are prior verbal ability, positive attitudes to mathematics, and at grade 8 level, socioeconomic status and sociocultural background.

Conclusions

There are many influences on student achievement in mathematics and science. Ideally the search to identify those influences should utilise longitudinal data so that characteristics of students, classrooms and schools could be related to changes in achievement. This investigation utilised cross-sectional data but focused specifically on mathematics and science achievement by making allowance for differences in students' verbal abilities and their social backgrounds.

The investigation reveals that most of the variation in mathematics and science achievement arises from differences among students rather than their classrooms or schools. The sources of this variation include verbal ability, socioeconomic and sociocultural background and interest. Even though interest in mathematics and science is conceptualised as a characteristic of individuals it can be shaped by the ways mathematics and science are taught. The sources of interest may be individual and therefore attention to the interests of individuals within classrooms may be important to nurture understanding and achievement.

Much of the difference among classrooms and schools in mathematics and science achievement is a reflection of the composition of the school or classroom. If the class is one with high average levels of developed verbal ability mathematics and science achievement is higher. Resources that students bring to the classroom influence the learning that takes place. This represents a dilemma in that achievement can be enhanced for some at the expense of others. The study did not identify any effects of teacher background or approaches to teaching mathematics on achievement. It is hard to capture the detail of what happens in classrooms from teachers' answers to survey questions. However, in the more detailed studies of unusually effective (and ineffective) classrooms, it was found that issues of student management (less lateness, absence, misbehaviour) might be associated with higher levels of achievement. These findings are consistent with those from other countries that participated in TIMSS. Home and school influences on student achievement are closely interwoven. Schools that draw their students from affluent communities are also likely to have more experienced and better-qualified staff and disentangling the contributions of these interactive influences is difficult. This study has shown that it is important to consider not just what teachers contribute to the learning process but what students also contribute.

Introduction

In the mid 1990s, Australia joined more than 40 other countries, from most regions of the world, in taking part in the Third International Mathematics and Science Study (TIMSS). The study was initiated by the International Association for the Evaluation of Educational Achievement (IEA), a large, non-governmental association of educational research centres which has been carrying out international achievement surveys since the early 1960s. The IEA's headquarters are currently in Amsterdam. According to its own brochures, the association's main aim is 'to conduct comparative studies focusing on educational policies and practices in order to enhance learning within and across systems of education'.

As the TIMSS name indicates, there have been two previous international studies of mathematics and science achievement. The earlier ones differed from TIMSS in that the two subject domains were investigated in separate studies. The first and second mathematics studies took place in 1964 and 1980-82. Corresponding dates for the first and second science studies were 1970-71 and 1983-84. Numbers of countries taking part and world regions represented in the first and second studies were limited in comparison with TIMSS, which is by far the largest and most comprehensive study undertaken to date.

Australia participated in all of the mathematics and science surveys except the second international mathematics study. For timing reasons, instead of waiting for the development of new tests for the second international study, which was subject to delayed schedules, the 1964 tests were used again in Australia in 1978. Changes over this 14-year time period were therefore able to be studied in relation to the same tests, and have been described by Rosier.[1] There have been several international reports and one or more national Australian reports produced from each of the first and second studies, which are listed in a separate Bibliography as an appendix to this book. There have also been several published reports of results from TIMSS, which are included in the Bibliography and also in the References section, as relevant.

Benefits of international studies

Countries differ in the ways their school education is organised, in the curricula they offer, in the preparation required of their teachers, in the styles their teachers use to present the curricula, in their expectations of students, and in many other factors potentially related to effective teaching and learning. The researchers who established the IEA wanted to study organisational and curriculum-related issues that could not easily be investigated in a single school system or country. They believed that naturally occurring differences from country to country in the ways that education is organised and delivered would provide a ready-made 'laboratory' for studying relationships of such factors with student achievement.

Different countries probably have different purposes for participating in studies such as TIMSS. A range of purposes is both possible and justifiable from the nature of the data. Possible purposes include: determining what are reasonable upper limits to expect of their students; understanding their students' achievements in an international context; examining the effects of a major curriculum reform; gauging where reform might be needed; stimulating the allocation of more funds for education; and monitoring where the areas of greatest educational need lie in their own country. IEA studies have become increasingly rigorous in their design and standardisation of procedures, necessary for making valid inferences from their results. TIMSS had by far the most rigorous quality control procedures of any IEA study to date,[2] thereby offering an excellent source of data for investigating questions related to purposes such as those listed here.

With funding becoming more scarce and the need for better educated populations, countries around the world are becoming more and more concerned about how to achieve best value for their education spending. The underlying challenge for a study such as TIMSS will always be to determine more about effective teaching and learning. Making use of the Australian (and some international) TIMSS data, this book is another step towards providing some answers about effective teaching and learning of mathematics and science in Australian primary and secondary schools.

Organisation of the book

To set the context, an overview of TIMSS and Australian primary and secondary students' achievement is provided in Chapter 1. A review of literature about earlier studies which have investigated a wide range of school, teacher and student factors in relation to mathematics or science achievement is presented in Chapter 2, to set the boundaries for the analyses and results that form the main part of this book. The review focuses on large-scale studies. The decision was taken not to attempt to review literature about the myriad of smaller studies, investigating one or two variables at a time in relation to achievement. For one thing, this would have been a never-ending task, and, for another, it would have been unlikely to reveal more than has already been reported from the larger-scale studies about variables that are separately related to achievement.

In the context of the more sophisticated analyses that form the main part of the present work, it is, however, useful to bear in mind the results from the analyses of one or two variables at a time that have already been carried out with the Australian TIMSS data for the initial Population 1 and Population 2 reports.[3] Results of the most relevant of these analyses are presented in Chapter 3 of this book.

The material presented from Chapter 4 onwards is new, and contains the results of the secondary analyses undertaken for this book. Chapter 4 deals with the derivation of composite variables from the student questionnaire data and contains the results of regression analyses undertaken to identify the most useful clusters of student variables in terms of accounting for differences in mathematics and science performance. In Chapter 5, multivariate procedures were carried out to identify useful clusters of variables related to teachers, their beliefs about mathematics and science, and their beliefs about mathematics and science teaching. Chapter 6 contains some descriptive information about the TIMSS schools but also identifies clusters of variables for use in the multilevel analyses of the interplay of the many contextual variables that operate at different levels in relation to students' schooling. The results of the multilevel analyses of achievement in relation to clusters of variables identified in Chapters 4 to 6 are presented and discussed in Chapter 7. Chapter 8 provides a summary and some conclusions with policy implications.

Notes

1 M. J. Rosier, *Changes in Secondary School Mathematics in Australia, 1964-1980*. Australian Council for Educational Research, Melbourne, 1980.

2 M. O. Martin & I. V. S. Mullis (eds), *Third International Mathematics and Science Study: Quality Assurance in Data Collection*. Boston College, Chestnut Hill, Massachusetts, 1996.

3 J. Lokan, P. Ford, & L. Greenwood, *Maths and Science on the Line: Australian Junior Secondary Students' Performance in the Third International Mathematics and Science Study*. TIMSS Australia Monograph No. 1, Australian Council for Educational Research, Melbourne, 1996; and

J. Lokan, P. Ford, & L. Greenwood, *Maths and Science on the Line: Australian Middle Primary Students' Performance in the Third International Mathematics and Science Study*. TIMSS Australia Monograph No. 2, Australian Council for Educational Research, Melbourne, 1997.

Chapter 1

TIMSS in a Nutshell

Scope

With students from five grade levels from a total of 45 countries taking part, and achievement in two major curriculum areas assessed, TIMSS was a massive project. In total, more than half a million students from more than 30 000 classes in more than 15 000 schools provided data. Not only were comprehensive mathematics and science tests developed for the study, there were questionnaires responded to by the students, their teachers and their school principals. Prior to the development of the tests, an extensive analysis of textbooks and curriculum documents was carried out. Mathematics and science curriculum experts from each country also completed questionnaires about the placement of and emphasis on a wide range of mathematics and science topics in their country's curricula. There is thus an unprecedented range of contextual variables to examine in relation to the TIMSS mathematics and science achievement measures.

Target student populations

Three target population levels were specified for TIMSS participation:

Population 1:	the two adjacent grade levels containing the largest proportion of nine-year-old students at the time of testing;
Population 2:	the two adjacent grade levels containing the largest proportion of thirteen-year-old students at the time of testing;
Population 3:	the final year of secondary schooling (some specialist sub-groups were also defined at this level).

For Populations 1 and 2, the original TIMSS design specified a minimum of 150 randomly-selected schools per population per country, with two classes randomly selected to participate from each of the adjacent grade levels within each selected school. Many countries were concerned about the cost of collecting data from samples of this size. The design was therefore modified to two classes at the upper grade and one at the lower. In practice, most countries also backed away from this compromise position. The USA, Australia and Cyprus were the only countries which selected and tested more than one class per grade level per school.

To be a member of TIMSS, a country had to participate in the Population 2 component. In most countries this involved testing students in grades 7 and 8. Participation in the other population components was optional. Just over half of the countries took part in each of the Population 1 and Population 3 data collections, with only partial overlap in the groups of countries participating at these levels. The countries which took part in the Population 1 and Population 2 components can be seen in the tables of results later in this chapter. Results from the Population 3 component are not presented because the further analyses undertaken for this book pertain to Populations 1 and 2 only.

Research model

Curriculum aspects and other educational indicators

TIMSS continued the practice begun in the second IEA mathematics study of focusing attention on three levels of the curriculum, all considered in relation to the context in which they occur. The three curriculum levels are:

- the *intended* curriculum—the curriculum as specified at national or system level;
- the *implemented* curriculum—the curriculum as interpreted and delivered by classroom teachers; and
- the *attained* curriculum—that part of the curriculum which is learned by students, as demonstrated by their attitudes and achievements.

The relationship of the curriculum levels to their relevant contexts and the range of TIMSS instruments is illustrated in Figure 1.1.

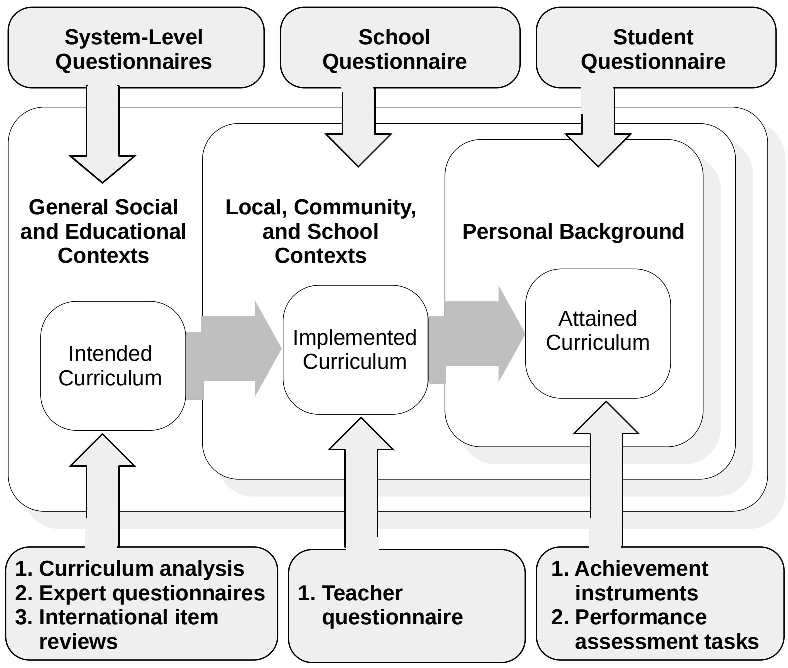

Figure 1.1 Relationship of the TIMSS Instruments to the Curriculum Aspects[1]

TIMSS has also been influenced by the literature on educational indicators,[2] which tends to view the complex interactions of teaching and learning in terms of 'inputs' and 'outputs'. In this literature inputs have a strong fiscal focus as well as pedagogical foci. One framework which had some impact on the overall model of educational opportunity developed for TIMSS is shown in Figure 1.2.

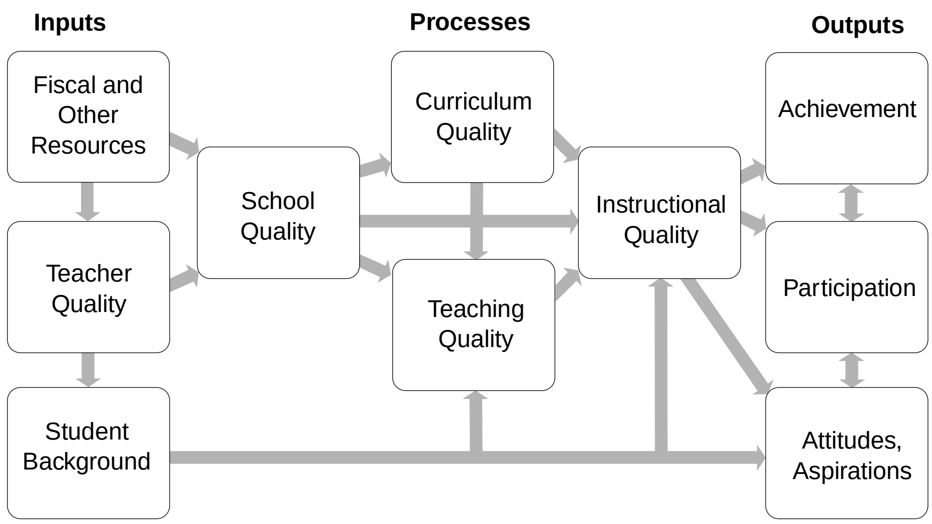

Figure 1.2 An Input-Process-Output Model of an Education System[3]

Major research questions guiding TIMSS

Four main general research questions arising from the above and similar models guided the development of TIMSS.[4] Each of these questions suggests a large number of more specific questions; some of these are addressed in this report, others form the basis of earlier reports and still others must wait for later reports. The four general questions centre around the following areas:

1 The 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 The implemented curriculum

> *What opportunities are provided for students to learn mathematics and science? How do instructional practices in mathematics and science vary among countries, and what factors influence these variations?*

3 The 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' achievements?*

4 Relationships of curricula to social and educational contexts

> *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?*

Combining the research questions into TIMSS' model of educational opportunity

The four main research questions were combined in the model of educational opportunity developed for TIMSS, shown here as Figure 1.3. The model shows the four questions across the bottom and the range of contextual variables at home, school system, school and class level as columns corresponding to the appropriate research question. The right-most column depicts the 'outcomes of the educational process'—that is, student achievement.

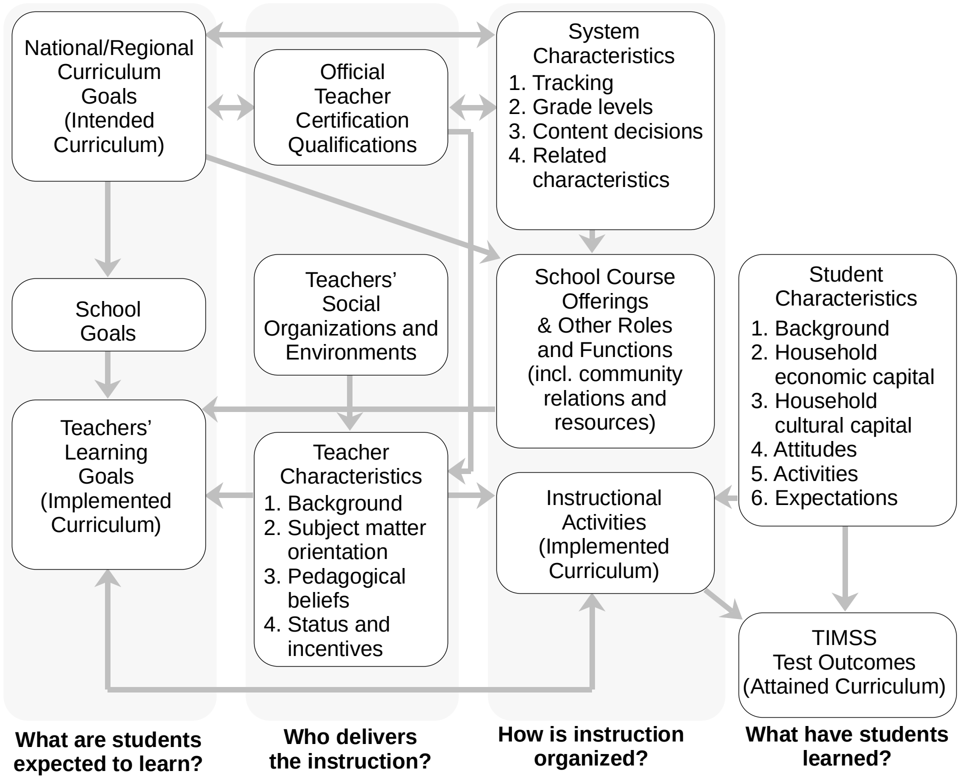

Figure 1.3 TIMSS' Conceptual Framework for Educational Opportunity[5]

Summary of Population 1 and Population 2 instrument coverage

Achievement tests

Wide coverage of topics and processes in the TIMSS mathematics and science tests was achieved through a design in which the items were grouped into 26 clusters of from 10 to 18 items each per population, and the clusters were rotated through eight test booklets per population. Some items appeared in all eight booklets, some were included in half the booklets, down to some which were included in only one booklet. The booklets within a population were created to be of about equal difficulty and to be answered in 90 minutes at Population 2 and 64 minutes at Population 1. Each student did only one test booklet and each booklet contained a mixture of mathematics and science items. About 15 items in each of mathematics and science were common to some of the test booklets across populations.

The written achievement tests were each made up of multiple choice items (about 70 per cent of the items) and items requiring either short or extended constructed responses. There were also some hands-on performance assessment tasks, requiring use of equipment, administered to subsamples of about 500 students per population. This component of TIMSS is not discussed further in this book, as the student samples were too small for the kinds of analyses that form the focus of the book to be carried out on the performance assessment data.

Mathematics coverage

Altogether there were 107 and 157 mathematics items spread across the Populations 1 and 2 tests, respectively. Items in ‘Whole numbers’, ‘Fractions and proportionality’ and ‘Measurement, estimation and number sense’, each represented about equally, made up two-thirds of the Population 1 test. Items in ‘Geometry’, ‘Data representation, analysis and probability’ and ‘Patterns, relations and functions’, also represented about equally, made up the remaining third of the test. At Population 2, items in ‘Fractions and number sense’ comprised a third of the test, another half was made up of items in ‘Geometry’, ‘Algebra’ and ‘Data representation, analysis and probability’, each represented about equally, and the remainder was made up of items in ‘Measurement’ and ‘Proportionality’.

Each item was also categorised according to the main skill required to answer it successfully. At Population 1, two-fifths of the items emphasised basic knowledge, two-fifths required carrying out routine or complex procedures, with a slightly greater emphasis on the latter, and one-fifth required investigating and/or problem solving. At Population 2, a third of the items required investigating and/or problem solving and the other three performance categories were represented about equally in the other two-thirds of the items.

Science coverage

In science, there were altogether 101 and 140 science items spread across the Populations 1 and 2 tests, respectively. The Population 1 test had ‘Life science’, with two-fifths of the items, as its main area of emphasis. Items in ‘Physical science’ and items in ‘Earth science’ made up a further third and a further fifth of the test, respectively. A smaller percentage of items focused on ‘Environmental issues and the nature of science’. At Population 2, items in ‘Life science’ and ‘Physics’ each made up a little under a third of the test, items in ‘Earth science’ and ‘Chemistry’ each made up almost a sixth, and again there was a small percentage of items in ‘Environmental issues and the nature of science’.

In terms of skills required, almost half of the Population 1 science items emphasised understanding of simple information, another thirty per cent emphasised understanding of complex information, and about a fifth required higher level processes such as analysing and solving problems. A small percentage of items required use of routine procedures and science processes. Understanding of simple or complex information were also the major emphases of the Population 2 science items, though to a slightly lesser extent than at Population 1. About a quarter of the Population 2 items required higher level processes such as theorising, analysing and solving problems, or investigating the natural world. There were also a few items requiring use of routine procedures and science processes.

Questionnaires

The questionnaires developed for TIMSS were based on a thorough review of the school, teacher and student factors which had been shown in previous research to be related to student achievement. Separate questionnaires were developed for principals, mathematics teachers, science teachers and students. Without consideration of the economic, cultural and educational contexts in which student achievement occurs, it would not be possible to draw conclusions from the achievement data that would be of use to education policy makers interested in initiating or evaluating reforms. Altogether, TIMSS collected responses to about 1500 contextual questions, many of which were included in the analyses presented and discussed in later chapters of this book.

Briefly:

- the School Questionnaire sought information about school characteristics (location, size, year levels catered for, and so on), resources, time for collaborative planning, and curriculum offerings;
- the Teacher Questionnaires asked about teacher qualifications and preparation, how teachers organise and carry out instruction in mathematics or science both in general and with reference to a particular lesson, use of homework, use of textbooks and other resources, and views on current issues in mathematics or science education; and
- the Student Questionnaire collected demographic information, data on how students spend their time both in and out of school, and their own and their parents' expectations and attitudes towards mathematics and science.

The major focus of this book is on identifying the most influential of the contextual factors in relation to student achievement. The variables derived from the questionnaires are elaborated in the chapters describing the analyses in which they were used.

Achieved samples

Almost 29 000 Australian students took part in the TIMSS testing in the final term of 1994 and the third term of 1995. Testing of Populations 1 and 2 students took place in 1994 in southern hemisphere countries, about five months ahead of the northern hemisphere testing. For Population 3, the reverse occurred in that the Australian final year secondary school sample was tested from August to October 1995, about five months after the northern hemisphere testing.

In Australia, about 12 500 students were sampled from Population 1, about 14 500 from Population 2 and about 4000 from Population 3. About 11 250, 13 700 and 3200 responded to the tests in these populations, respectively. Schools in each sample were selected randomly, with probability proportional to their enrolment size within their state or territory, from all education systems throughout the country. The students came from more than 450 schools. Whole classes were sampled randomly within schools at Populations 1 and 2, while individual students were sampled randomly at Population 3.

At Populations 1 and 2, the populations of interest for this book, over 330 principals responded to the School Questionnaire and about 1500 teachers responded to Teacher Questionnaires. The distributions of student respondents by state and territory are presented in Table 1.1.

Table 1.1 Distributions of Student Respondents by State and Territory

Sample	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Population 1									
Actual N	1937	1345	2405	1593	1603	978	607	780	11 248
Weighted N	3701	2685	2091	766	1134	445	174	252	11 248
Population 2									
Actual N	2227	2258	2542	2061	2316	1228	534	538	13 704
Weighted N	4297	3387	2517	1004	1328	538	220	429	13 704

Summary of Australian Population 1 and Population 2 results

TIMSS reporting scales

TIMSS used Item Response Theory (IRT) methods to create reporting scales in each of mathematics and science for each population separately. Internationally, these scales were given the arbitrary mean value of 500 and standard deviation of 100 for the upper and lower grade levels combined in each of Populations 1 and 2. Over all countries at Population 2, there was a difference of 29 scale points in mathematics (from 485 to 514) and 37 scale points in science (from 481 to 518) between the upper and lower grade means. At Population 1, the corresponding lower to upper grade achievement differences were 59 for mathematics (from 470 to 529) and 51 for science (from 473 to 524) over all countries. The Population 1 differences indicate achievement change between grades of half a standard deviation or more at the middle primary level, while the Population 2 differences indicate achievement increments between grades of only about a third of a standard deviation at lower secondary level.

The Australian results summarised here are reported in detail in the first two national TIMSS reports.[6] Readers who wish to know more of the international results should consult the Population 1 and Population 2 international reports.[7]

Results on total tests by upper and lower grade in Australia

Table 1.2 presents a summary of the Australian and the international Population 1 results on the total mathematics and total science tests. The Australian results were significantly higher than the international results in all instances. The overall international mean of 500 and standard deviation of 100 were determined for the upper and lower grades combined. The table shows that, within either the upper or the lower grade, the spread of scores (as indicated by the standard deviation) was a little less than that for the grade levels combined.

Table 1.2 Australian and International Achievement Results, Population 1

	Australia		International	
Subject area	**Mean**	**SD**	**Mean**	**SD**
Mathematics, upper grade	546	92	529	97
Mathematics, lower grade	483	90	470	91
Science, upper grade	562	93	524	95
Science, lower grade	510	98	473	95

Table 1.3 shows the analogous results for Population 2. Australia’s results in science were significantly higher than the international results. In mathematics, our results were only one scale score point below the level required for a significant difference from the international mean at the upper grade and two scale score points below the level required at the lower grade.

Table 1.3 Australian and International Achievement Results, Population 2*

	Australia		International	
	Mean	**SD**	**Mean**	**SD**
Mathematics, upper grade	530	98	514	**
Mathematics, lower grade	498	92	485	**
Science, upper grade	545	106	518	**
Science, lower grade	504	103	481	**

* These results are weighted and are based on the scores of the Australian students included in the international data set (see Table 1.1).

** The international standard deviations were not included in the international reports. From the country by country values reported, the international values would be expected to be a little less than 100, as they were for Population 1.

Australia's results in relation to other countries' results - Total Tests

Population 1

Twenty-six countries participated in mathematics and 24 participated in science at Population 1. At the upper grade, only six countries performed better than Australia in mathematics and only two countries performed better in science on the total tests. At the lower grade, our students acquitted themselves even better, with only four countries performing at a significantly higher level in mathematics and only one doing so in science. Details of achievement by country are given for the upper grade in Table 1.4 and for the lower grade in Table 1.5. These tables also show the countries that achieved significantly higher than, at the same level as, and significantly lower than Australia.

Table 1.4 Results by Country, Population 1 Upper Grade

Mathematics

	Country	Average
	Singapore	625
	Korea	611
↑	Japan	597
	Hong Kong	587
	Netherlands*	577
	Czech Republic	567
	Austria*	559
	Slovenia*	552
	Ireland	550
	Hungary*	548
=	**Australia***	**546**
	USA	545
	Canada	532
	Israel*	531
	Latvia*	525
	Scotland*	520
	England*	513
	Cyprus	502
↓	Norway	502
	New Zealand	499
	Greece	492
	Thailand*	490
	Portugal	475
	Iceland	474
	Iran, Islamic Rep.	429
	Kuwait*	400

Science

	Country	Average
	Korea	597
↑	Japan	574
	USA	565
	Austria*	565
=	**Australia***	**562**
	Netherlands*	557
	Czech Republic	557
	England*	551
	Canada	549
	Singapore	547
	Slovenia*	546
	Ireland	539
	Scotland*	536
	Hong Kong	533
	Hungary*	532
	New Zealand	531
↓	Norway	530
	Latvia*	512
	Israel*	505
	Iceland	505
	Greece	497
	Portugal	480
	Cyprus	475
	Thailand*	473
	Iran, Islamic Rep.	416
	Kuwait*	401

* These countries did not meet one or more of the international sampling criteria.

Table 1.5 Results by Country, Population 1 Lower Grade

Mathematics

	Country	Result
	Korea	561
↑	Singapore	552
	Japan	538
	Hong Kong	524
	Czech Republic	497
	Netherlands*	493
	Slovenia*	488
	Austria*	487
=	**Australia***	**483**
	USA	480
	Hungary*	476
	Ireland	476
	Canada	469
	Latvia*	463
	Scotland*	458
	England*	456
	Thailand*	444
	New Zealand	440
↓	Cyprus	430
	Greece	428
	Portugal	425
	Norway	421
	Iceland	410
	Iran, Islamic Rep.	378

Science

	Country	Result
↑	Korea	553
	Japan	522
	USA	511
=	**Australia**	**510**
	Austria	505
	England	499
	Netherlands	499
	Czech Republic	494
	Canada	490
	Singapore	488
	Slovenia*	487
	Scotland*	484
	Hong Kong	482
	Ireland	479
	New Zealand	473
↓	Latvia*	465
	Hungary*	464
	Norway	450
	Greece	446
	Iceland	435
	Thailand*	433
	Portugal	423
	Cyprus	415
	Iran, Islamic Rep.	356

* These countries did not meet one or more of the international sampling criteria.

Population 2

Results analogous to those shown for Population 1 in Tables 1.4 and 1.5 are shown for Population 2 in Tables 1.6 and 1.7. Forty-one countries participated in the Population 2 upper grade testing and 39 took part in the lower grade testing. As for Population 1, these tables show the countries that achieved significantly higher than, at the same level as, and significantly lower than Australia. It can be seen that at the upper grade, eight countries performed better than Australia in mathematics but only four countries performed better in science on the total tests. At the lower grade, seven countries performed at a significantly higher level than Australia in both mathematics and science, though not always the same countries.

Table 1.6 Results by Country, Population 2 Upper Grade

Mathematics

	Country	Result
	Singapore	643
	Korea	607
	Japan	605
↑	Hong Kong	588
	Belgium (Flemish)*	565
	Czech Republic	564
	Slovak Republic	547
	Switzerland*	545
	Netherlands*	541
	Slovenia*	541
	Bulgaria*	540
	Austria*	539
	France	538
	Hungary	537
	Russian Federation	535
=	**Australia***	**530**
	Ireland	527
	Canada	527
	Belgium (French)*	526
	Thailand*	522
	Israel*	522
	Sweden	519
	Germany*	509
	New Zealand	508
	England*	506
	Norway	503
	Denmark*	502
	USA*	500
	Scotland*	498
	Latvia*	493
	Spain	487
↓	Iceland	487
	Greece*	484
	Romania*	482
	Lithuania*	477
	Cyprus	474
	Portugal	454
	Iran, Islamic Rep.	428
	Kuwait	392
	Colombia*	385
	South Africa	354

Science

	Country	Result
	Singapore	607
↑	Czech Republic	574
	Japan	571
	Korea	565
	Bulgaria*	565
	Netherlands*	560
	Slovenia*	560
	Austria*	558
	Hungary	554
	England*	552
	Belgium (Flemish)*	550
=	**Australia***	**545**
	Slovak Republic	544
	Russian Federation	538
	Ireland	538
	Sweden	535
	USA*	534
	Germany*	531
	Canada	531
	Norway	527
	New Zealand	525
	Thailand*	525
	Israel*	524
	Hong Kong	522
	Switzerland*	522
	Scotland*	517
	Spain	517
	France	498
	Greece*	497
↓	Iceland	494
	Romania*	486
	Latvia*	485
	Portugal	480
	Denmark*	478
	Lithuania*	476
	Belgium (French)*	471
	Iran, Islamic Rep.	470
	Cyprus	463
	Kuwait	430
	Colombia*	411
	South Africa	326

* These countries did not meet one or more of the international sampling criteria.

Table 1.7 Results by Country, Population 2 Lower Grade

Mathematics

	Country	Result
	Singapore	601
	Korea	577
	Japan	571
↑	Hong Kong	564
	Belgium (Flemish)*	558
	Czech Republic	523
	Netherlands*	516
	Bulgaria*	514
	Austria*	509
	Slovak Republic	508
	Belgium (French)*	507
	Switzerland*	506
	Hungary	502
	Russian Federation	501
	Ireland	500
	Slovenia*	498
=	**Australia***	**498**
	Thailand*	495
	Canada	494
	France	492
	Germany*	484
	Sweden	477
	England*	476
	USA*	476
	New Zealand	472
	Denmark*	465
	Scotland*	463
	Latvia*	462
	Norway	461
↓	Iceland	459
	Romania*	454
	Spain	448
	Cyprus	446
	Greece*	440
	Lithuania*	428
	Portugal	423
	Iran, Islamic Rep.	401
	Colombia*	369
	South Africa	348

Science

	Country	Result
	Singapore	545
	Korea	535
	Czech Republic	533
↑	Japan	531
	Bulgaria*	531
	Slovenia*	530
	Belgium (Flemish)*	529
	Austria*	519
	Hungary	518
	Netherlands*	517
	England*	512
	Slovak Republic	510
	USA*	508
=	**Australia***	**504**
	Germany*	499
	Canada	499
	Hong Kong	495
	Ireland	495
	Thailand*	493
	Sweden	488
	Russian Federation	484
	Switzerland*	484
	Norway	483
	New Zealand	481
	Spain	477
	Scotland*	468
	Iceland	462
	Romania*	452
↓	France	451
	Greece*	449
	Belgium (French)*	442
	Denmark*	439
	Iran, Islamic Rep.	436
	Latvia*	435
	Portugal	428
	Cyprus	420
	Lithuania*	403
	Colombia*	387
	South Africa	317

* These countries did not meet one or more of the international sampling criteria.

Australia's results in relation to other countries' results - Test Parts

At Population 1, Australia performed particularly well in Geometry and 'Environmental issues and the nature of science' in comparison with other countries. At Population 2, Australia's performance was high in relation to that of students in other countries in 'Data representation, analysis and probability', Algebra, Physics and 'Environmental issues and the nature of science'. Our students performed consistently poorly on questions requiring computation beyond addition of two numbers, for example on multiplication and division of fractions, simple division of decimals and computations involving more than two steps. Examination of their test papers revealed that their relatively poor performance on some of the problem solving items was mostly due to incorrect computations rather than to misunderstanding the problems or not knowing how to go about solving them. The computational demands of the items were not excessive, as evidenced by the high performance of students from more than half the participating countries.

Variation among the Australian states and territories

As has been the case in earlier IEA studies, differences in achievement were found among the Australian states and territories. The highest achieving group of states in each case was on a par with the highest achieving TIMSS countries. Even the lowest achieving of the Australian states were, in each case, at a level equivalent to the international average.

Previous Australian TIMSS reports

Full accounts of the basic Australian TIMSS results in both international and national perspective have been given in three reports, one per population.[8] These reports describe the schools, teachers and students who participated in the study; give detailed breakdowns of results on the test components as well as showing illustrative examples of test items with commentary about relevance to the Australian national profiles;[9] present and discuss achievement differences both internationally and between the Australian states and territories; and examine some of the context variables one by one in relation to achievement.

Results showing the relationships of selected context variables to achievement are reviewed in this report, both from TIMSS and from other studies, as a first step in the consideration of variables which are most likely to prove useful in explaining variance in achievement in more complex analyses. A digest of the most pertinent results from the separate Australian Population 1 and Population 2 reports is presented in Chapter 3, following the literature review in Chapter 2.

Need for extended analyses

In order to achieve timely publication of the basic findings, all the results presented in the previous Australian TIMSS reports were derived from separate analyses of data from students, teachers and schools. Such analyses do not do justice to the richness of the TIMSS data, however. Education is a complex phenomenon, with outcomes of schooling likely to be related to factors operating at all of these levels and interacting in complex ways.

In addition to the examination of correlation coefficients and/or mean achievement for various categories of a variable to show simple associations, some of which are illustrated in Chapter 3, there was clearly a need to use more sophisticated analysis techniques to obtain a perspective on the 'bigger picture' of variables interacting together and at different levels. Some of these techniques have become available relatively recently, post-dating the IEA second international mathematics and science studies, for example. Later chapters of this monograph report the results of both multivariate analyses, in which many variables were considered simultaneously, and multilevel analyses, in which school-, teacher- and student-level data were combined.

Notes

[1] From D. F. Robitaille, & R. A. Garden, Design of the study, Chapter 3 in D. F. Robitaille & R. A. Garden, (eds), *TIMSS Monograph No. 2: Research Questions & Study Design*. Pacific Educational Press, Vancouver, 1996.

[2] D. F. Robitaille & B. Maxwell, The conceptual framework and research questions for TIMSS, Chapter 2 in D. F. Robitaille & R. A. Garden, 1996.

[3] See Note 2. Diagram adapted from R. Shavelson, L. McDonnell, J. Oakes & N. Carey, *Indicator systems for monitoring mathematics and science education: A sourcebook*. Rand Corporation, Santa Monica, California, 1987.

[4] See Note 2.

[5] See Note 2. Diagram adapted from W. Schmidt, 1993, TIMSS: Concepts, measurements and analyses. Unpublished paper, TIMSS Document No. ICC618/NRC242.

[6] J. Lokan, P. Ford, & L. Greenwood, *Maths and Science on the Line: Australian Junior Secondary Students' Performance in the Third International Mathematics and Science Study*. TIMSS Australia Monograph No. 1, Australian Council for Educational Research, Melbourne, 1996; and

J. Lokan, P. Ford, & L. Greenwood, *Maths and Science on the Line: Australian Middle Primary Students' Performance in the Third International Mathematics and Science Study*. TIMSS Australia Monograph No. 2, Australian Council for Educational Research, Melbourne, 1997.

[7] A. E. Beaton, I. V. S. Mullis, M. O. Martin, E. J. Gonzalez, D. L. Kelly & T. A. Smith, *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*. Boston College, Chestnut Hill, Massachusetts, 1996;

A. E. Beaton, M. O. Martin, I. V. S. Mullis, E. J. Gonzalez, T. A. Smith & D. L. Kelly, *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*. Boston College, Chestnut Hill, Massachusetts, 1996;

I. V. S. Mullis, M. O. Martin, A. E. Beaton, E. J. Gonzalez, D. L. Kelly & T. A. Smith, *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study*. Boston College, Chestnut Hill, Massachusetts, 1997; and

M. O. Martin, I. V. S. Mullis, A. E. Beaton, E. J. Gonzalez, T. A. Smith & D. L. Kelly, *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study*. Boston College, Chestnut Hill, Massachusetts, 1997.

[8] See Note 6; and

J. Lokan & L. Greenwood, *Maths and Science on the Line: Australian Year 12 Students' Performance in the Third International Mathematics and Science Study*. TIMSS Australia Monograph No. 3, Australian Council for Educational Research, Melbourne, 2000.

[9] Australian Education Council, *Mathematics – a curriculum profile for Australian schools*, and *Science – a curriculum profile for Australian schools*. Curriculum Corporation, Melbourne, 1994.

Chapter 2

Review of Related Studies

Background

Reasons for achievement in mathematics and science (as in any area of school learning) are complex, involving a multitude of factors other than number of years of schooling. This secondary analysis of Australian TIMSS data investigated the influence of a range of student, teacher, and school variables on student achievement in mathematics and science, both individually and collectively. Several different statistical techniques, including hierarchical linear modelling (HLM) (also known as *multilevel modelling*), were used.

The student, teacher and school factors were chosen because of their potential as predictors in more complex analysis than has been carried out on these data in the past. The selection of factors was based partly on findings of prior research, representative examples of which are reviewed in this chapter. The review makes no claim to be exhaustive, as there are a great many studies of factors related to mathematics achievement or science achievement that have been carried out in a more limited way. Rather, the review focuses on large-scale studies in which factors at several levels (for example, school, class, student) have been measured, and in which some kind of multivariate analyses (that is, of variables acting in combination) have been done.

It is only in the past 10 to 15 years that computer programs have become readily available to carry out, in an efficient way, the analyses that take into account the hierarchical nature of data collected in institutions such as schools. The process of education usually involves students and teachers working together within classrooms within schools. In their turn, schools function within systems. Just as there is usually wide variability in student and teacher characteristics and behaviours, there is also variability between schools and between education systems. There are many variables at different levels of this hierarchy that have the potential to affect the outcomes of education, and typically do so. It is appropriate, in fact advantageous, to provide for the level at which variables have been measured to be taken into account in analyses of factors contributing to educational outcomes. A brief introduction for non-specialist readers to the development and use of multilevel techniques of data analysis is included below, following the discussion of student-level variables.

Student background variables

The importance of family background variables in the context of student achievement has been studied by researchers for at least 50 years. Different emphases have been pursued by different groups of researchers, resulting in a very large volume of literature. A comprehensive review of the work up to the late 1970s is provided by Marjoribanks.[1] This review commonly reports correlations in the range .25 to .35 of socioeconomic status, as evidenced by parents' education, father's occupation and family income, with achievement. The correlations became higher when certain 'environmental press' variables (for example, parents' expectations for the child; family involvement in educational activities) were considered in conjunction with socioeconomic status. An Australian review published in 1995 by Ainley, Graetz, Long and Batten[2] substantiated similar levels of correlation between indices of socioeconomic status and educational achievement as those reported 16 years earlier by Marjoribanks.

The importance of the student's home background was reinforced by Burstein, Fischer, and Miller, who noted in 1980:

> When viewed at the individual pupil level, measures of family background can reflect differences between pupils in a given school. When aggregated over the pupils who attend a given school, measures of family background can describe community characteristics such as economic, social class, and ethnic mixture.[3]

Further, a feature of the TIMSS analyses reported for 41 countries in the main international reports was the similar relationship of achievement with aspects of home background (for example, number of books in the home) that held across all countries.[4]

Several student background variables were available for analysis in the TIMSS data. These included gender, age, ethnicity, mother's and father's occupations and levels of education, number of books in the home, number of items in the student's home (such as dictionary, computer, own wardrobe) and family size. The relationship of these variables to mathematics and science achievement has been addressed in studies over many years. Of most relevance to the present context are studies which considered these kinds of variables in a composite way, several of which are reviewed here.

In their 1973 analysis of the science component of the Six Subject Survey sponsored by the International Association for the Evaluation of Educational Achievement (IEA), Comber and Keeves set up a block of variables, *Home Circumstances*, comprising father's occupation, father's education, mother's education, use of dictionary, books in the home, and family size. Regression analysis was carried out on data from three populations of students, Populations I, II, and IV. Population I consisted of students from 10:0 to 10:11 years at the time of testing; Population II of students aged from 14:0 to 14:11 at the time of testing; and Population IV of students who were 'in the terminal year of those full-time secondary education programs which were either pre-university programs … or programs of the same length' (pp. 9-10). Populations II and IV included Australian students. Within Population II the mean percentage of variance in student achievement accounted for by the variable *Home Circumstances* across all countries was 16% (also 16% for Australia). Across all countries in Population IV the mean percentage of variance in student achievement accounted for by *Home Circumstances* was 14% (13% for Australia).[5]

Larkin and Keeves, using path-analysis techniques,[i] reported moderately strong between-classes correlations in 1984 as follows:

- father's occupation and student's occupational aspirations, .34;
- father's occupation and student's educational aspirations, .33;
- student's prior achievement and student's educational aspirations, .52; and
- student's prior achievement and educational aspirations, .64.

However these authors commented that 'in the absence of prior achievement [father's] occupational status was not a good predictor of student achievement'.[6] This result may indicate the presence of a mediating variable such as home educational level which is strongly associated with prior achievement but weakly associated with occupational status per se.

---

i 'Path' analyses are similar to regression analyses, and allow pathways of relationships from antecedent to outcome variables to be hypothesised and checked for validity. Some examples are presented for Australian students in Chapter 4.

In 1985, Bourke investigated classroom context and teaching practice variables at the Year 5 level in Australia using multiple linear regression and path analysis techniques.[7] The variable *Student Characteristics* was drawn from the IEA Classroom Environment Study[8] and comprised:

- age;
- sex;
- aspirations for further education;
- general attitude towards school;
- initial achievement; and
- initial attitude towards the subject matter being taught.

Bourke estimated a path coefficient from *Student Characteristics* to *Achievement* of .626, and from *Student Characteristics* to *Enjoyment* of .414. Although family socio-economic status was not a component of the variable *Student Characteristics* it may nevertheless underlie items (3) to (6) above.

The 1986 study of De Graaf is of interest in this context. De Graaf investigated the relationships between student socioeconomic status, family cultural resources, and student achievement in Dutch primary and secondary schools over an extended period. Socioeconomic status comprised father's and mother's education and father's occupational prestige score. Cultural resources were defined in terms of the frequency of family visits to libraries, the theatre, museums, and historical buildings plus hours of serious reading per week.

De Graaf's concern was to test the claims, made in the 1970s and early 1980s, of Bourdieu, Collins and Passeron[9] that student achievement is strongly determined by parents' cultural resources (as distinct from financial resources alone) by comparing two distinct periods of school education in the Netherlands. In 1950 the Dutch government took over funding of all primary and secondary education in the Netherlands, whether in state or private schools. From 1950 onwards, therefore, a family's financial resources might be expected to contribute less to student achievement than before 1950.

In order to gauge the contribution of cultural resources to student achievement, De Graaf surveyed two cohorts of former students. Members of the first cohort had completed their schooling before 1950 and members of the second had started their schooling in 1950 or after. He concluded from his study that a family's cultural resources did not in fact constitute a good predictor of student achievement. In contrast, student socioeconomic status was found to be a strong predictor. He noted that:

> the correlation between social background [i.e. socioeconomic status] and formal culture [i.e. family cultural resources] is .65 for the older cohort and .59 for the younger cohort, which clearly illustrates the strong relationship between educational and occupational characteristics and participation in formal culture.[10]

The strength of these correlations led De Graaf to reject the hypothesis that family cultural resources predict educational attainment:

> The strong associations between formal culture climate and family educational attainment (r = .44 for the older cohort and r = .41 for the younger cohort) … are completely spurious. The social background variable predicts both the lifestyle and the educational attainment of the family.[11]

In fact, it appears that De Graaf obtained similar findings to those highlighted by Marjoribanks in his 1979 review: that prediction of achievement is enhanced when aspects of the home educational environment are considered together with socioeconomic status.

Another 1986 study, that of ‘Parental Involvement, Homework, and TV Time: Direct and Indirect Effects on High School Achievement’ carried out by Keith and colleagues, posited the variable *Family Background* which comprised father’s occupational status, mother’s and father’s educational attainment, family income, and possessions in the home. Path coefficients relevant to the present section of this study were:

- family background and achievement, .115;
- family background and ability, .297; and
- ability and achievement, .597.[12]

Marjoribanks continued working in the area of family background and achievement for many years. In a 1987 study of the mathematics performance of 11-year-old Australian children in relation to a range of family variables, he reported a single correlation of .22 between social status (defined as an equally weighted composite of father’s occupation and the education level of both parents) and mathematics achievement.[13] This level of relationship seems low in comparison with that found in most studies.

The IEA Classroom Environment Study investigated a variable called *Home*, comprising father’s occupation and, depending on the participating country, one or more of the following variables: father’s education, mother’s education, and similarity of the student’s home language with the language used in the school. Surprisingly, *Home* was not found to contribute significantly to student achievement:

> Interestingly, HOME does not directly affect either POSTTEST [the amount of learning acquired by the student in the course of the study] or POSTATTSUBJ [the student’s attitude towards the target subject at the conclusion of the study], nor does it directly influence PREATTSUBJ [attitude towards the target subject at the beginning of the study] or ATTSCH [attitude towards school]. Rosier & Banks (1990)[14]

More typically, the following studies found a significant relationship between variables based on students’ home environment and their educational achievement. In the Second International Science Study (SISS) done in Australia in the early 1980s, Rosier and Banks found that the variable *Socio-Educational Level* (SEL), consisting of a combination of

- father’s occupation;
- father’s and mother’s secondary education;
- father’s post-secondary education;
- number of books in the home; and
- home use of a dictionary

correlated well with students’ *Combined Science Test Score*: .30 for Population 1, (10-year-olds), and .36 for Population 2, (14-year-olds). There was also a strong correlation between *SEL* and a variable which Rosier and Banks call *Ability*. This variable was constructed on the basis of student performance on a word knowledge test and on a mathematics test. For Population 2 the path coefficient for *SEL* and *Ability* was .37, for *Ability* and science achievement .54, and for *SEL* and science achievement .12. A variable, also named SEL, was constructed in an analogous way for TIMSS by Lokan et al., and similar relationships with achievement in both mathematics and science at Populations 1 and 2 were found.[15]

As studied by Young and Fraser in 1993, the variable *Home Background* consisted of:

- father’s occupation;
- mother’s occupation;
- father’s education;
- mother’s education;
- family size; and
- use of dictionary

These authors found the correlation of *Home Background* with student science achievement to be .298.[16] Also in 1993, Schmidt and Burstein noted that 'In the absence of a pretest control, social class status is correlated with prior achievement in most systems [in the IEA second mathematics study] and, as a result, was found to be significantly related to the post test results'.[17]

Thus,

> it becomes clear that the well established relationship of social class to achievement portends only an indirect effect and that once its understood impact on achievement is controlled for at the outset of the school year (i.e., the pretest), it has little or no direct effect on the growth in achievement realized during the … year.'[18]

In some preliminary analyses of TIMSS data in 1996, Zabulionis, as reported by Brekke, Kjarnsli, Lie and Zabulionis, developed a partial least squares model to compare the degree to which different background factors influenced the achievement of Population 2 mathematics students in the Czech Republic, Lithuania, and Norway. Since science is taught as a single, unified subject in Norway, whereas it is split into distinct subjects in the Czech Republic and Lithuania, Zabulionis was also able to model the influence of background factors on the science achievement of Population 2 students in Norway. A variable *HSOS* was defined, based on:

- home possessions indicating a high degree of disposable family income,
- nationality of family, and
- parent status (student living with both parents).

Interestingly, this variable did not correlate with either mathematics or science achievement for any of the countries in the study. However, another variable, *HEDP*, did show a weak positive correlation with mathematics achievement in all three countries and with science achievement in Norway. *HEDP* reflected the educational environment of the home, and was defined as a composite of the students' perceptions of the importance their mothers attached to education, the number of books in the home, and the number of education-directed possessions in the home. In the final model used in the study the path coefficient for *HEDP* and mathematics achievement for the Czech Republic was .140, for Lithuania .170 and for Norway .132. For science in Norway the path coefficient for *HEDP* and achievement was .145.[19]

In a recent secondary analysis of the TIMSS Population 2 (age 13) mathematics data, Bos and Kuiper (1999) presented results across ten education systems, namely: Belgium (Flemish), Belgium (French), the Czech Republic, Denmark, England, Germany, Lithuania, the Netherlands, Norway, and Sweden. These authors used the number of books in the student's home as a proxy for the educational level of the student's mother and father. Owing to missing data on other variables, this variable, which is designated *Home Educational Background*, was the only student background variable included in their study. Path coefficients for *Home Educational Background* and mathematics achievement obtained in the ten countries varied from .11 in Flemish Belgium to .31 in Germany and .32 in England. Most were between .20 and .26.[20]

Zabulionis (1997) examined factors affecting the mathematics achievement of Grade 8 students in nine Central and Eastern European countries that had taken part in TIMSS: Bulgaria, the Czech Republic, Hungary, Latvia, Lithuania, Romania, the Russian Federation, the Slovak Republic, and Slovenia. The correlation across these nine countries between the variable *Home Educational Background*, comprising:

- mother's education;
- father's education;
- and
- number of books in the home,

and mathematics achievement was found to be .31.[21]

There is thus abundant evidence that students' home backgrounds do predict the success that students have at school. Personnel at all levels of the schooling enterprise share the belief however that schools and teachers can influence students' learning outcomes. There are other reasons why societies establish schools, but, given the beliefs that young people need to be educated and persons trained to impart knowledge and skills will succeed in doing so, the main reason is that it is more efficient to group students formally for instruction than to rely on informal methods. Researchers and policy makers have been eager for many years to discover the factors related to school structures and teaching practices which would add to (or counteract) students' home backgrounds in improving the outcomes of schooling for students. The next section begins with reference to one of the most significant pieces of research in this respect – significant largely through its unexpected results and its consequent impact on research methodology.

Multilevel analyses

In 1966 the report of the *Equality of Educational Opportunity* study, now commonly referred to as 'the Coleman report', appeared in the United States. The study was initiated in response to the Civil Rights Act of 1964 and the researchers' brief was to report on 'the lack of availability of equal educational opportunities for individuals by reason of race, color, religion, or national origin in public educational institutions' (Civil Rights Act of 1964, Section 402). The study was expected to serve as a basis for educational and, more generally, social reform. However, the study arrived at a surprising conclusion: it appeared that schools had little effect on student achievement. What really counted, it appeared, was the student's socio-economic background.[22] The Coleman study thus seemed to cast doubt on the possibility of improving student achievement through reforms to schooling.

It was soon realised that the analysis methods used in the Coleman study, where data were aggregated at school level, suppressed much information that might have been useful in helping to account for student achievement. Researchers and data analysts were prompted to re-examine a number of methodological assumptions and practices. This program of re-examination led to a number of advances in statistical methodology, in particular the development of techniques for taking into account the various levels of hierarchy in education systems and schools, when studying factors related to achievement.

Put simply, it was recognised that models were needed that could specify how effects at each level of the hierarchy (system, school, class, student, with country added to the list if an international study) influence processes occurring at the other levels. Even if schools or teachers provided exactly the same learning circumstances for all their students, individual student responses, and hence class responses, would vary. The same teacher in the same school teaching the same subject to two classes would probably vary the teaching in response to differences in rapport established between the teacher and the classes, or in response to differences in students' ability. As stressed by Bryk and Raudenbush, two of the 'prime movers' in the debate, it is methodologically erroneous to 'disaggregate' school or teacher variables to students in a single level analysis as though the school experience was identical for all students in the school.[23] Many of the studies considering student, teacher/class and school variables that have been reviewed so far suffered from this lack of appropriate methodology.

The other reason for recognising the multilevel structure of schooling is a technical one, that of ensuring that standard errors of the estimates of effects derived from statistical analyses are calculated appropriately, as explained in 1991 by Paterson. Ordinary regression techniques give error terms that are misleadingly small when used with multilevel data. The important consequence of this is that confidence intervals for testing the significance of results are deceptively small, which can lead to errors of over-interpretation of effects. With each level of analysis, extra levels of uncertainty are introduced which are ignored in single-level analyses. Paterson gives the example of two students with the same SES, but attending different schools. There will be a genuine association of SES with achievement for these students, but also unknown factors that could be influential as a result of differences between the schools. In any analysis that ignores schools, the effects of unmeasured influences would be under-stated.[24]

Thus, the need for models to explain (i) how student-level variables influence outcomes, and (ii) interaction effects across levels, was recognised. During the 1980s computer programs for hierarchical analysis began to appear, though they were initially not user-friendly and hence were not widely used. Advances in programming in the past decade have led to wider availability of software that is easier to use, though a fair degree of expertise is still needed to set up the analyses and interpret the results. It should be noted that multilevel models are still not a solution to all the data analysis problems in educational research, because they are based on assumptions about the data that might not be met in the real world (for example, normality of distributions).[25] Further, they allow only one outcome variable to be examined at a time. Nevertheless they represent a large advance on single-level analyses with disaggregated data because of the increased statistical precision in estimating error variance.

For interest, results pertaining to student background from a few studies in which multilevel techniques were used are summarised here. In a very early study using multilevel techniques, Burstein, Fischer, and Miller found a between-schools correlation of student achievement with father's occupation of .610 in the USA, .601 in England, and .221 in Sweden, leading them to observe that:

> the US, which allows local officials the greatest discretion in decision-making and finance, has strong between-schools effects for father's occupation … our best indicator of the wealth of the local community. At the other extreme, the Swedish system seeks to equalize school resources through administrative centralization; thus between-schools differences associated with social class are virtually non-existent.[26]

In 1990, Bosker, Kremers, and Lugthart developed and tested a multilevel instructional and school effects model of pupil achievement, using large-scale data from the Netherlands. They noted that:

> It appears that the higher the educational level of the parents, the better the achievement of the pupils on the tests [biology, English, Dutch, and mathematics]. This trend can be seen for each subject, if we take the results from all school types together. This trend is caused by the unequal participation of certain pupils in the higher valued general secondary school types. In the Dutch education system these pupils' parents tend to have a high level of education themselves.
>
> Within school types we do not see this trend. There is no systematic relation between the level of education of the parents and the achievement on the tests.[27]

Multilevel analyses of the Australian data from single-sex boys schools that took part in the Second International Science Study, as reported by Kotte, showed a similar result to that found in the Netherlands: home background was not related to achievement in science at age 14, within school type. The same did not hold for single-sex girls schools, where home background operated through an aptitude variable to influence achievement.[28]

In a 1991 study, Garner and Raudenbush presented a more complex picture. These authors used HLM techniques to estimate the '*direct* effect of living in a socially deprived area over and above other factors of influence, such as individual ability, family circumstances, and schooling', on the educational attainment of 2500 young people who left school between 1984 and 1986 in a particular Scottish school district. After controlling for pupil ability (based on a verbal reasoning test and a reading ability test); family background (father's occupation, level of parental education, family size, one-parent family status, and father's employment status); and type of schooling, 'a significant negative association between deprivation in the home neighbourhood and educational attainment' was found.[29]

Student mediating variables

Several student-level variables that can be considered as likely to mediate relationships of home background to achievement are briefly reviewed here.

‘Gender’ is not a mediating variable in the same sense as the attitudinal and belief variables included in this section. However it is also different from the socioeconomic and educational environment of the home variables that formed the focus of the early part of this chapter. In several of the studies reviewed already, gender of student was one of the variables included in a student background composite. In many other studies, gender has been the focus of interest. No attempt is made here to review that literature in full, as it could easily occupy a whole book. One very comprehensive study is of particular interest however, given that it was based on IEA data and utilised path analysis methods similar to those employed in several of the studies already reviewed. This was the study published in 1992 by Kotte, in which gender was examined in the context of home background, teaching emphasis and school facilities variables in predicting science achievement and attitudes. Kotte carried out separate path analyses for ten countries, including Australia. Gender was found to have a direct negative relationship with achievement, indicating higher results for boys, in seven of the ten countries. The largest coefficients were obtained for the Netherlands and Thailand. The three countries with no significant path for gender were Finland, Japan and Sweden.[30]

Student verbal ability is likewise different from attitudinal variables, but is an important variable in relation to achievement. The Word Knowledge test was developed for IEA studies by Thorndike to provide a control variable on verbal ability.[31] A major aim in devising the test was translatability into languages other than English. The test presents the student with a number of word pairs and requires the student to decide whether the words in each pair are (near) synonyms or (near) antonyms. It was used in the First and Second International Science Studies (FISS and SISS) and appears as a useful variable in the reports of those studies.[32] It was also used in studies reported by Bourke and Keeves in 1977[33] and by Burstein, Fischer, and Miller in 1980.[34] Bourke and Keeves reported correlations of .51 and .55 between word knowledge and numeracy achievement at ages 10 and 14, respectively, and of .59 and .67 between word knowledge and reading score for the same age groups. Rosier and Banks reported correlations of similar magnitude, around .55, between word knowledge and science achievement for both the 10-year-old and the 14-year-old Australian samples in SISS.

Slightly modified versions of Thorndike’s original tests were included in the TIMSS Student Questionnaires in Australia because of the increasingly verbal nature of the mathematics and science achievement tests. Inclusion of a ‘control’ variable for verbal ability seemed to be as important for TIMSS as it was for FISS and SISS, although this was not done internationally. The results from TIMSS Populations 1 and 2 in Australia are reviewed in Chapter 3 of this book.

In their report of the first science study, Comber and Keeves established a block of student mediating variables designated *Kindred Variables*. The constituents of this block varied somewhat according to which population was being examined. For Population I (age 10) the constituents of the *Kindred Variables* block were:

- liking of school;
- school motivation;
- whether parents helped with homework;
- hours TV watched per day; and
- hours reading for pleasure.

The *Kindred Variables* block for Populations II (age 14) and IV (Year 12) contained more variables and variables of a more specific kind (for example, time spent reading science and technical books). Regression analysis showed the mean contribution of *Kindred Variables* to total variance across the countries in Population I to be 6% with a range of 10. The mean contribution of the Population II block to total variance was 5% with a range of 10; and the mean contribution of the Population IV block to total variance was 5% with a range of 19.[35]

Larkin and Keeves obtained the following path coefficients for science achievement regressed on

- student's occupational aspirations, .10;
- educational aspirations, .14;
- academic motivation, .06;
- liking of school, .05; and
- participation in maths/science activities, .05 (p. 43).

It can be seen from these coefficients that the relationships of such variables with achievement, from the work of both the above studies, are quite low, though in the expected positive direction.

Keith, Reimers, Fehrmann, Pottebaum and Aubey used path analysis techniques to 'determine the direct and indirect influences of parental involvement, homework, and TV time on seniors' achievement while controlling for other relevant influences'. The variable *Parental Involvement* was based on students' responses to five questions measuring student perception of parental involvement (for example, 'My parents … almost always know where I am and what I am doing'). The direct path coefficient from *homework* to *achievement* was .141, that from *Parental Involvement* to *homework* was .158, while that from *Parental Involvement* to *achievement* was -.005. The direct path coefficient from *Parental Involvement* to *TV time* was .044; and from *TV time* to *achievement* was -.056.[36]

In the IEA Classroom Environment Study, Anderson and colleagues found that the variable *Aspiration*, based on students' aspirations for further education, had a positive effect on their pretest attainment; for example, the direct path coefficient for Australian students was .26 and the median path coefficient for all countries was .28. The corresponding path coefficients for pretest to post-test were .67 and .48, respectively.[37] Keeves examined cross-national studies of science achievement from 1970 to 1984. He commented in his 1992 report that:

> the science attitudes and values held by individual students influence the level of achievement of those students in science, after other factors such as the home background and aptitude of the students are taken into account. Likewise, the average levels of attitudes and values held by the classroom group of students also have an influence to change the level of achievement on science of the classroom group after allowances are made for home background and aptitude effects.[38]

In preliminary analyses of TIMSS data, Brekke, Kjarnsli, Lie and Zabulionis reported that a construct *Attitudes to Mathematics* had been set up, consisting of positive student responses to five attitude items, for example, 'I like learning mathematics' and 'Mathematics is boring'. For the final model, the direct path coefficient for this construct and achievement was .181 for the Czech Republic, .181 for Lithuania, and .175 for Norway. The variance explained by this was 18.2%, 35.8%, and 29.3% respectively. Because of the nature of science education in Norway, it was possible to establish a construct *Attitudes to Science* specific to Norway; the path coefficient of the composite variable and science achievement was .175 and the explained variance was 33.5%.[39]

In Bos and Kuiper's analysis of TIMSS data from ten European countries, the construct *Attitude towards Mathematics* was based on student responses to five questions relating to enjoyment of mathematics and five relating to students' perceptions of the importance of mathematics. Path coefficients for *Attitude towards Mathematics* and mathematics achievement were not significant for England and Germany. For the other education systems they ranged between .12 for the Netherlands and Lithuania and .22 for Norway.[40]

Zabulionis, analysing TIMSS data from nine central and Eastern European countries, developed two constructs: *Like Math*, based on five enjoyment/interest variables; and *Importance of Math*, based on students' perception of the importance of mathematics for work, for securing a job, and for life. For the final regional model (that is, for all nine countries), the path coefficient for *Like Math* and mathematics achievement was .16 and the path coefficient for *Importance of Math* and mathematics achievement was .02.[41]

In summary, the student-level variable of word knowledge is likely to be much more highly related to achievement than attitudinal/motivational variables such as some of those reviewed in this section. Word knowledge, of course, is also related to SES and educational environment of the home. The multivariate and multilevel analyses carried out on the Australian data for this book shed some light on the complex inter-relationships between the various student background and mediating factors included in the Australian TIMSS data sets. As Kotte's study showed, gender was an important variable in explaining achievement differences in SISS for some countries, not so for others. Gender differences in achievement were reported for many countries in TIMSS, but were almost non-existent in the Australian data.[42]

Teacher factors

Data on some 20 teacher variables, covering the areas of gender, age, training, workload, access to facilities, and opportunities for professional development, were collected in the first international science study. Regression analysis was carried out for Populations I, II, and IV using a selection of these teacher variables within a block designated *Learning Conditions in the School*. The components of this block varied according to the population under consideration and the block contained classroom factors as well as teacher factors. Consequently, the results of the regression analysis are discussed in the following section of this report, Classroom factors.

Some research findings of Martin, who studied teacher effectiveness in small-group instruction in the late 1970s, were discussed by Burstein in an article published in 1980. The significance of Martin's study from the perspective of research on TIMSS is methodological, as a pioneering application of multilevel analysis ideas in research on teacher effectiveness. Reanalysing data from the Texas First Grade Reading Group Study, Martin:

> estimated the regressions of posttest on pretest, teacher behavior, and the interaction of pretest and teacher behavior at three levels: between-class, reading-group-within-class and student-within-reading-group.[43]

Teacher behaviours included selection variables (how students were selected to give information) and feedback behaviours.

In an extensive review of research into teacher behaviour and learning outcomes published in 1980, Centra and Potter proposed a structural model of the influence of school and teacher variables on student learning outcomes.[44] Most of the categories within this model had appeared as variables in an earlier report by McDonald and Elias.[45] Teacher characteristics in the Centra and Potter model were:

- qualifications;
- experience;
- aptitudes;
- knowledge of subject;
- knowledge of teaching;
- values and attitudes;

- expectations; and
- social class.

A problem highlighted by Centra and Potter was lack of correspondence in teacher variables across studies:

> Thus, comparison of … studies requires careful scrutiny of both the definition and the measurement of the teacher behavior variables in question; this equivalence cannot be assumed and is generally difficult to measure.[46]

On the positive side, however, Centra and Potter observed that:

> if several investigators, working in different subject areas, with different measures of teacher behavior, have studied variables that are conceptually similar, and have found significant correlations between particular categories of teacher behavior variables and student achievement (however defined and measured), these categories of teacher behavior are worthy of further investigation and should be measured in any comprehensive study of classroom processes.[47] (p. 282)

Among the key findings of McDonald and Elias, noted by Centra and Potter, were these:

- Teachers do make a difference;
- There are no single teaching-performance variables which in themselves correlate so highly with student achievement that they should be considered critical for effective teaching. In fact, relatively few teaching-performance variables, when considered alone, were found to be significantly related to student growth; and
- Differences in patterns of teaching performance accounted for difference in student learning.

A wide range of teacher variables was included in Larkin and Keeves' 1984 study, but no results relating these to achievement were reported – the study's purpose was to investigate the effect of class size on student achievement.[48] Bourke's 1985 study, on the other hand, investigated the effects on student achievement of the variable *Teacher Characteristics*, taken from *The IEA Classroom Environment Study* and broadly similar in content to the set of teacher variables in Larkin and Keeves. It comprises sex, age, years of teaching experience, type of certification, training in subject matter, and workload.

Bourke found a path coefficient for *Teacher Characteristics* and the variable *Classroom Context* of .222 and a path coefficient between *Classroom Context* and enjoyment of mathematics of .324. No significant path coefficient was found for *Teacher Characteristics* and student achievement, however. Several classroom variables that did correlate significantly with both student achievement and enjoyment were identified ($r \geq .19$); among these was a variable which may also be considered a teacher variable, namely teacher job satisfaction.[49] Internationally, a correlation of .297 between *Teacher's Years of Experience* and student achievement was found.[50] A rather puzzling and inconclusive finding by Bosker, Kremers, and Lugthart in 1990 was that teacher job satisfaction correlated positively with the mathematics achievement of boys in Dutch schools (.18) but negatively (-.33) with the mathematics achievement of girls.[51]

Schmidt and Burstein found, in relation to the Second International Mathematics Study, that 'variables describing teachers, classroom instruction, and schools' make up a complex picture. For example, these variables 'are in general more predictive of achievement differences within the United States than they are for the other seven educational systems' covered in the study. Further:

> although only nine of these [teacher, classroom, and school] characteristics are statistically significantly related to growth in achievement in some subtest area for at least one system, no variable that is statistically related to achievement is replicated in more than two instances in a consistent direction.[52]

The teacher-specific variables examined in this study were *Years of Experience* in teaching mathematics to Population A (basically Year 8) students and *Teacher's Degree of Specialization*, that is, the number of periods spent teaching mathematics divided by total number of teaching periods.

Classroom factors

Blocks of classroom-related variables were included in many of the studies cited so far. An example is provided by Comber and Keeves in the report of the first science study, in which three distinct blocks of classroom variables were investigated. Each block was designated *Learning Conditions in the School*. The block for Population I (students aged 10) contained the following variables:

- teaching methods: use of audio-visual materials;
- grade level of students in the sample;
- size of class;
- students have regular science lessons;
- students have a textbook for science;
- students make observations and do experiments; and
- students make up own experiments and design experiments.

The mean contribution of this block, from between-school regression analysis, to the total variance of student achievement in Population I was 15%. Chile ranked highest at 36%, and England and Japan lowest at 2%. The mean contribution from between-student regression analysis was 8%. Belgium (French) ranked highest at 21% and Japan lowest at 1%.

For Population II (students aged 14) the components of *Learning Conditions in the School* were:

- percentage of school teaching staff who are male;
- number of laboratory assistants;
- sex of science teachers in sample;
- opportunity to learn items tested;
- school behaviour scale;
- homework in science (a composite variable); and
- study in science (composite variable: currently taking science, total study of science in years, total hours current study of science).

The mean contribution of these variables to total variance from between-school regression analysis for Population II was 15%, Sweden ranking highest at 44% and Scotland lowest at 3%. From between-student regression analysis the mean contribution was 9%; Thailand ranked highest at 23% and Japan lowest at 4%.

Finally, for Population IV (Year 12), *Learning Conditions in the School* consisted of:

- total enrolment;
- percentage of teachers male and teaching science (composite variable);
- sex of science teachers in sample;
- number of ancillary staff (composite);
- teacher training (composite);
- teaching methods;
- opportunity to learn items tested;

- homework per week;
- total science homework per week; and
- study of science (composite).

The mean contribution of these variables to total variance (between-school regression analysis) for Population IV was 18% with Sweden highest at 30% and France lowest at 6%. Mean contribution to total variance (between-school regression analysis) was 17%; Scotland was the highest at 34% and Iran the lowest at 4%.[53]

In their study of the effects of class size, Larkin and Keeves investigated 44 classroom variables. When student mathematics achievement, controlled for father's occupational status, was regressed on these variables, just over half of the correlations obtained were of no practical significance (less than .10). The variables with the highest positive correlation were *Total Time on Mathematics*, .19, and *Invitation to Inquire*, also .19.[54]

In reporting the Australian component of the IEA Classroom Environment Study, Bourke presented a number of correlations of classroom variables with mathematics outcomes at the Year 5 level, among them the following: use of textbooks was positively correlated with achievement (r = .32) and negatively correlated with enjoyment (-.22). Use of worksheets, concrete materials and curriculum packages were positively correlated with enjoyment (respectively, r = .26, .28, and .23). Teacher's perception of class ability correlated positively with achievement (r = .53), but negatively with enjoyment (r = -.20). Average group size was positively related to achievement (r = .41) and negatively related to enjoyment (r = -.24). In classes where comprehension of concepts was emphasised student achievement was higher (r = .22), but in classes where students were expected to follow rules student enjoyment was greater (r = .21).[55]

In the same study internationally, Anderson, Ryan, and Shapiro considered a substantial number of classroom variables. These included:

- typical use of grouping;
- observed use of grouping;
- use of types of materials;
- lesson emphasis;
- lesson objective;
- class size;
- number of adults per classroom;
- student attendance;
- teacher perceptions of relative class ability;
- teacher perceptions of percent of students needing remediation;
- amount of homework;
- opportunity to learn;
- allocating time;
- instructional time;
- specifying objectives;
- reviewing content; and
- about 50 items involving teacher-student interaction in class.

For Australia the meaningful correlations with residualised post-test scores were as follows:

- laboratory seatwork, -.242;
- silence, .286;
- discipline, -.285;

- years of teaching experience, .297; and
- opportunity to learn rating, .352.[56]

Reviewing findings from the 1992 US National Assessment of Educational Progress (NAEP), Silver, Strutchens and Zawojewski reported significant associations with mathematics achievement of several instructional variables operating at class (or school) level. Among these variables were opportunity to learn, reflected in course-taking patterns; easy access to instructional resources; instructional time; amount of homework assigned; and classroom use of textbooks, calculators and computers.[57]

As noted in the previous section, Bosker, Kremers, and Lugthart found a surprising negative correlation between the variable *Classroom Climate* (that is, teacher's job satisfaction) and girls' achievement. Commenting on the study as a whole, the authors stated:

> The results show that it is hard to distinguish instructional and teacher effects from school effects and that there are complicated cross-level interactional effects on achievement.[58]

In general, the findings of this study need to be interpreted in light of the stratification of the Dutch secondary education system, in which the main school types are senior grammar, senior secondary, and junior secondary (the two largest subgroups within this last category being technical and domestic science schools). Bosker, Kremers and Lugthart noted 'a remarkable gap between the level of student achievement from junior vocational schools and general secondary schools: the first group achieves much less than the second group'.[59]

Rosier and Banks did not find strong correlations in SISS for Population 1 (10-year-olds) between any of the variables *Practical Work, Teacher Initiated Activities,* or *Student Initiated Activities* and student achievement. For example, *Practical Work* was unrelated to achievement in all States and Territories except South Australia, where a low but significant negative path coefficient was found (-.09). For Population 2 the variable *Time* was positively related to student achievement in five of the eight states/territories, with the highest path coefficient obtained in Tasmania (.18). *Practical Work* was positively related to achievement in three states/territories, the ACT having the highest path coefficient at .15, and not related in the rest. The variable *Teacher Support* had a low, positive relationship with achievement in Queensland alone and the variable *Recapitulation* had a low, negative relationship with achievement in NSW alone. On the other hand, the variable *Student Initiated Activities* correlated quite strongly, but negatively, with achievement for seven of the eight states/territories (ranging from -.09 in Western Australia to –.21 in the Australian Capital Territory).[60]

For SIMS, Schmidt and Burstein determined between-group coefficients for the following classroom variables:

- hours spent doing homework;
- proportion of class in bottom third nationally;
- hours mathematics allocated to content in specified subtest areas;
- class hours of mathematics per week;
- implemented coverage ('Opportunity to Learn' – OTL);
- hours of homework in all subjects; and
- class size.

As noted in the 'Teacher factors' section of this review, Schmidt and Burstein found that student characteristics related more closely to growth in achievement than to characteristics of classroom instruction, schools, or teachers. The variable *Opportunity to Learn* was the only classroom or school variable significantly related to achievement growth in more than one system after controlling for other student and school variables. However, 'even for OTL the results are spotty and inconsistent'.[61]

Brekke and colleagues defined the following variables for their preliminary TIMSS analysis:

- *School and Class Climate*, a construct based on students' responses to questionnaire items concerning prevalence of theft and injury at the school, and students' readiness to skip classes;
- *Homework*; and
- *Teacher-dominated style.*

They obtained the following final model path coefficients for these variables and student achievement:

- Czech Republic, mathematics: positive school and class climate, .146; homework, 0; teacher-dominated style, -.49;
- Lithuania, mathematics: positive school and class climate, .106; homework, .063; teacher-dominated style, .57;
- Norway, mathematics: positive school and class climate, .055; homework, .083; teacher-dominated style, .119; and
- Norway, science: positive school and class climate, .060; homework, .057; teacher-dominated style, .074.[62]

Zabulionis considered the variables *Classroom Climate* (briefly characterised as: students neglect schoolwork, students are quiet in lessons, students do as teacher says) and *Teaching Style* (teacher-dominated/student-centred) in the nine-country European analysis, but these dropped out of the final model through having non-significant relationships with achievement.[63]

- The Bos and Kuiper study for ten European countries examined the following classroom variables:
- homework;
- *Teaching style* (teacher-/student-centred);
- *Class Climate*: students neglect schoolwork; students are orderly and quiet; students do exactly as teacher says;
- *Instructional Formats*: extent of cooperative learning;
- class size;
- effective learning time;
- *Assessment*: degree to which teacher assesses and bases decisions on results of assessment; and
- teacher expectation.

These researchers found that in the majority of cases the path coefficients for the classroom variables and student achievement in mathematics were not significant. They concluded:

> Considering the low R^2 of the three endogenous latent variables class climate, effective learning time and instructional formats plus the low or non-significant path coefficients from these latent variables towards achievement in mathematics ... one can conclude that these factors cannot be kept in the model unless better indicators (manifest variables) ... can be found in the TIMSS data.[64]

School Variables

A thorough review of literature on school-level characteristics associated with school effectiveness was provided by Banks in 1992.[65] Three general dimensions of schools were identified: academic press; staff and parent engagement; and school ecology. The first two are largely under the control of schools and therefore of interest to policy makers, the third generally not open to decision making at local level (for example, school size and collective attributes of the student body). Banks found that mean science class time was not correlated with achievement in science. A weak negative effect of class size was found for primary schools but a moderately strong positive effect on science scores was found for secondary schools. Amount of science homework had a positive effect on science achievement. Banks also concluded that:

> Academic Press was generally an important and positive influence on student performance in the cognitive outcomes of schooling and therefore, this aspect of schools may be described as a value-adding factor in the dynamics of schools.[66]

Banks found that greater levels of Academic Press were associated with larger or smaller learning gaps, depending on the intake characteristic and the outcome measure. The 'staff and parent engagement' measures showed only very slight value-adding effects, and in inconsistent directions. School size showed a weak, positive influence on achievement in primary schools but not in secondary schools.

To examine the effects of school variables, Comber and Keeves established the block of variables *Type of School*. This block was based partly on the type of program offered by the school (academic, vocational, general, or unclassified) and partly on other variables that had been found to function as stratifying variables within countries. Among such variables were the following:

- number of students;
- student/teacher ratio;
- urban-suburban location;
- percentage of male teachers;
- total ancillary staff;
- variety of courses;
- single sex;
- has PTA; and
- position on school behaviour scale.

For Population I the mean variance explained by this block of variables was 1%; for Population 2, 6% (7% for Australia); and for Population IV, 7% (3% for Australia).[67]

In their 1977 study of Australian schools Bourke and Keeves set up the following blocks: *School Location* (metropolitan, non-metropolitan), *Type of School* (Government, Catholic, Independent), and *State* (State or Territory). These blocks of variables were analysed as predictors for mean school word knowledge. At the 10-year-old level the amount of variance explained by the three blocks was 12.9%; at the 14-year-old level it was 34.3%.[68]

Centra and Potter, in their 1980 review of school and teacher effects studies, observed that:

> between-schools studies have not been successful in identifying school (or district) characteristics that are highly related to how much students learn. Although schools apparently do make some difference, most of the variability in student achievement is related to student social class or to within-school factors.[69]

The variables investigated by Centra and Potter, and which gave rise to the comment that studies have not been successful in identifying school characteristics related to achievement, were:

- school or School District conditions;
- sex of student;
- word knowledge;
- father's occupation;
- books in home;

- years of study;
- science instruction;
- instructional approach.

Within-School Conditions:

- administrative organisation;
- instructional organisation:
  - tracking;
  - team teaching;
  - open vs. traditional;
- student peer group influences;
- class size;
- quantity of schooling; and
- environment or ambience.

In the mid 1980s, Lee and Bryk investigated a range of complex attitude, achievement, and school indicators in their study of single-sex versus coeducational schooling in the USA. Using the US *High School and Beyond* project as its basis, this study took a random sample of 1 807 students in Catholic high schools, 45 of which were single-sex. Lee and Bryk stated:

> We compared the effects of these two types of school organization on the nature of students' engagement in school life in terms of their social and academic attitudes, school-related behaviors, and courses of study. We also investigated the impact of single-sex education on students' academic achievement, educational aspirations, self-concept, and views of adult sex roles.[70]

The conclusions of Lee and Bryk, broadly speaking, were that single-sex education appeared to be of benefit to students and that further research into the question was warranted. Although these conclusions are not in themselves directly relevant to the purpose of the present study, the range of school variables considered by Lee and Bryk is given below.

- boys only;
- coeducational;
- girls only;
- school size;
- student/faculty ratio;
- diversity of curricular offerings;
- % female faculty;
- % faculty with advanced degrees;
- % annual faculty turnover;
- % faculty at school 10 years or more;
- first salary step, BA;
- annual tuition;
- per-pupil expenditure;
- perceived quality of teaching;
- general school rating; and
- % religious order.

Anderson, Ryan, and Shapiro, in the IEA Classroom Environment Study, also investigated the variables *School Location*, *School Type¸Grade Levels*, *School Size*, and *Subject Hours*. However, these variables did not appear in their Core Model as contributing to achievement.[71]

In another study based on the High School and Beyond data, Lee and Bryk conducted a complex investigation of student achievement in US Catholic and public schools, concluding tentatively that the ethos of the former tends to encourage academic achievement, especially among minority groups. The quantitative aspects of this study are not amenable to a brief summary; however, the substantive conclusion of the study was that:

> a distribution of achievement that maintains a high average level, as well as being socially equitable, is more likely to arise when the average level of academic course taking is high and the differences among students' programs of study are small.[72]

The school variables considered in their study were as follows:

- school composition:
  - average school social class;
  - percentage of high-minority schools;
  - average academic background;
- teacher quality:
- teacher interest;
- staff problems;
- perceived quality of instruction;
- social climate:
- disciplinary climate;
- percentage of students who feel safe;
- perceptions of authority as fair and effective;
- academic climate:
- average hours a week on homework;
- attitude toward academics;
- average lack of academic press;
- curricular communality:
- average number of mathematics courses;
- standard deviation of mathematics courses; and
- percentage of students in the academic track.

Bosker and Scheerens, reporting a study in the Netherlands in the late 1980s, found that 11% of the variance in mathematics achievement was accounted for by the schools that the pupils attended.[73] It should be noted, however, that the generalisability of this finding is problematic, given the particular stratified characteristics of schooling in the Netherlands.

Mandeville and Kennedy, in their 1991 study of reading and mathematics achievement in 9700 South Carolina students as they progressed from Grade 1 to Grade 3, examined a range of school-level predictor variables, including size of school, level of teacher education, socioeconomic background variables, retention rates and school climate. They found that no clear links could be established between these variables and student achievement:

> Reading trends were effectively constant across schools and, therefore, not predictable based on school characteristics. The linear parameters for mathematics did exhibit true variation, accounting for about 25% of the total variation. Unfortunately, our 13 school level variables proved to be virtually unrelated to this variation with none of the 13 significant.[74]

Burstein, for the Second International Mathematics Study, considered the variables:

- school enrolment;
- class size;
- urban/rural;
- hours of mathematics per year; and
- school days per year.

The first four of these were generally found not to be significant across countries and the fifth dropped out of the analysis altogether.[75]

In the nine-country European analysis of TIMSS data, Zabulionis considered:

- community (urban/rural);
- school size; and
- school climate: theft, skipping class, injury.

In the final Regional Model, for all nine central and Eastern European countries combined, the path coefficient from *Community* to *Size* was .50, from *Size* to student achievement, .03, from *Size* to *School Climate*, -.16, and from *School Climate* to student achievement, .13. *School Climate* was thus potentially a more influential factor in students' achievement than was school size.

In a recent local study, Afrassa and Keeves examined factors influencing the performance of students in Years 3 and 5 in South Australia on the annual Basic Skills Test. A wide range of school level variables was considered, including mean age, gender composition, ethnic background composition, socioeconomic background variables, and numeracy and literacy levels, and concluded that:

> If variables are to be identified that have a consistent influence at the school level on the performance of students within the school in both Literacy and Numeracy and at both Year 3 and the Year 5 grade levels from the 20 variables examined, only two are found to have consistently significant effects. These two variables are:
>
> (a) proportion of Aboriginal and Torres Strait islanders in the school, and
> (b) proportion of school card holders in the school,[76]

the latter being an index of socioeconomic disadvantage.

Summary and discussion

This chapter has reviewed a small but targeted number of studies with a similar purpose to that of the secondary analyses of TIMSS – to identify factors pertaining to schooling that 'make a difference' as far as learning outcomes for students are concerned. Clusters of variables similar to those featured in TIMSS were a focus, as were large-scale studies examining variables at different levels of the hierarchy of schooling. The need to take account of this hierarchy, that is, of students within classrooms, classrooms within schools and schools within education systems, led in the 1980s to the development of computer programs to enable the effects of variables operating at the different levels to be separated out and estimated appropriately. The chapter includes a brief discussion of Hierarchical Linear Modeling (HLM), the method chosen for the secondary analyses of the Australian TIMSS data.

The review, together with the results of the primary analyses reported in the next chapter, informs the selection of variables for further investigation in the secondary analyses that form the main focus of this book. The consistent thread running through the studies reviewed is that student-level factors are the most powerful in accounting for achievement differences. Some studies successfully identified teacher- or classroom-level factors as having an influence on achievement, but the effects of these variables were typically relatively small compared with the effects of student-level factors. The same was true for school-level factors. Nevertheless, using the methods such as those employed by Banks, some schools have been and can be identified as having more 'value-added' effect than others, and it will be worth further examination of these schools in the quest for factors that can be manipulated to achieve better outcomes for students.

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Chapter 3

Some Pertinent Results from the Main Australian TIMSS Reports

To set the context for the secondary analyses of the TIMSS data that form the major part of this book, some key results at student level from the main Australian Population 1 and Population 2 reports are presented in this chapter. The variables for which results are shown here were partly suggested by the literature review in the previous chapter and partly by the actual TIMSS results.

In addition to the mathematics and science achievement variables, data on a large number of student characteristics and home background variables, attitudes and aspirations were collected. In order to release the main Australian TIMSS reports at the same time as the international reports, the student-level variables were mostly examined only one at a time in relation to achievement (as they also were in the main international reports). Results of such analyses prepare the way for the more complex analyses undertaken for this book, but can be overinterpreted without consideration of the way the many variables act together in relation to achievement.

Table 3.1 lists the main clusters of student-level variables on which data were collected. Most were included in the questionnaires at both populations, but the Population 2 questionnaire was a little longer and probed some areas in more detail.

As a first step in examining these many variables, the correlations between each of them and the outcome variables of mathematics and science achievement were computed. As expected, an inspection of the resulting correlations indicated the variables likely to be of use in further analyses and those that seemed unlikely to be so, but more definitive work in this vein was not undertaken at that stage. In the main TIMSS reports, only a small number of composite variables from the many possibilities were formed: namely, an index of socio-educational level of the home (to be consistent with earlier IEA studies of mathematics and science in Australia);[1] a composite of time on non-academic activities; a composite of time on academic activities; a composite ethnic and language background variable; and 'like mathematics'/'like science' variables.

In the next chapter of this book, the work of creating meaningful composites from the myriad of separate questionnaire items is extended well beyond that addressed in the main reports, as well as assembling the more detailed work into a series of inter-connected models predicting achievement. For information, the tables of basic correlations from the main reports are repeated here.

Table 3.1 Student-level Variables Included in Population 1 and Population 2 TIMSS Questionnaires

Cluster	Items, Population 1	Items, Population 2
Characteristic		
	Gender	Gender
	Age	Age
	Indigenous status	Indigenous status
	Verbal ability	Verbal ability
Home background		
	Family composition	Family composition
	Language, ethnicity	Language, ethnicity
	Education resources	Education resources
	Socioeconomic status	Socioeconomic status
		Parental education
	Parental valuing of mathematics/science	Parental valuing of mathematics/science
Behaviours		
	Out-of-school time in academic activities	Out-of-school time in academic activities
		Time in paid work
	Out-of-school time in non-academic activities	Out-of-school time in other non-academic activities
Attitudes		
	Engagement with learning	Engagement with learning
	Importance of mathematics/science	Importance of mathematics/science
	Enjoyment of mathematics/science	Enjoyment of mathematics/science
	Internal–external control beliefs	Internal–external control beliefs
	Self-assessment of abilities	Self-assessment of abilities
Aspirations		
		Plans for future education
Perceptions of their teaching		
	Activities during mathematics/science lessons	Activities during mathematics/science lessons
Achievement		
	Mathematics	Mathematics
	Science	Science

Correlational analysis

Achievement measures

The TIMSS mathematics and science tests, as mentioned in Chapter 1, had wide coverage of topics and skills considered to be important worldwide. About three-quarters of the items in each test were multiple choice and the remainder required either short written answers or, in a few cases, extended written responses. The items were assembled into eight booklets in a complicated design, with some parts of each booklet occurring in other booklets and some parts unique. Each booklet contained a mixture of mathematics and science items and each student responded to only one booklet. Population 2 students each answered about 70 items and Population 1 students each answered about 50 items. All but a small percentage of students were able to finish their booklet.

To make maximum use of the complex, linked design of the test booklets, Item Response Theory (IRT) methods were used to analyse the achievement data and create a mathematics score and a science score for each student. In effect, this methodology allows each student to be assigned a score as if he or she had attempted all of the test items. Measurement errors are minimised because the methodology takes into account large amounts of information, utilising the students' responses to the questionnaire items as well as to the test items. These methods have been used in the US National Assessment of Educational Progress (NAEP) since the early 1980s, and are ideal for a study like TIMSS where the main goal was to produce the most accurate estimates of achievement for populations.

Responses to questionnaire items

The TIMSS Student Questionnaires (one at each population level) gathered important background information about students and asked them a number of questions about their perceptions of learning mathematics and science. For ease of marking and data entry the possible responses were categorical. Examples include *yes* or *no*; *strongly agree*, *agree*, *disagree* or *strongly disagree*; and *almost always, pretty often*, *once in a while* or *never*. The responses were then coded numerically. By way of illustration, *strongly agree* was originally scored as a '1', *agree* was scored as a '2', *disagree* was scored as a '3' and *strongly disagree* was scored as a '4'.

For ease of interpretation, student responses on scale-type items were uniformly recoded so that positive opinions or occurrences such as *strongly agree* or *almost always* received the highest scores and negative opinions or occurrences received the lowest scores. The categorical values were reversed so that *strongly agree,* for example, was recoded from '1' to '4' and the other categories treated accordingly. Thus, for example, in the seventh row of Table 3.2, the positive correlation (0.27) between the higher of mother's/father's occupation and mathematics achievement indicates that those students who have a parent with a high level of education were more likely to score well in the mathematics test than those in their cohort with less well-educated parents. Likewise, a negative correlation such as that between the number of people living in the home and the mathematics score (-0.14) indicates that, in general, students who have a greater number of people living at home tended to score less well in the mathematics test.

Items that were answered on a 'yes' or 'no' basis were also recoded so that interpretation was more intuitive. Therefore positive correlations such as that of 0.27 between the student having a calculator at home and mathematics achievement would imply that students with access to a calculator at home are more likely to be those who score higher on the achievement measures. However these correlations should be interpreted in light of the survey results showing that 86 percent of the Population 1 respondents and 98 percent of the Population 2 respondents answered that they did have a calculator in their home.

For ease of viewing, the cells containing correlation coefficients of 0.10 or greater are highlighted in bold. Following common practice, probabilities are shown only for those correlations that are statistically significant.

Statistical significance and educational importance

One of the consequences of analysing relatively large data sets is that seemingly quite small influences assume statistical significance. Many of the Pearson product-moment correlations in Table 3.2 are statistically significant yet the practical importance of some of these factors is minimal. For example a correlation of -0.14, as described previously for the relationship between number of people living in the home and mathematics achievement, represents only about two per cent of shared variance.[i] It is worth noting here that the correlations reported in this study between variables usually taken as indicators of socioeconomic status are of the order found in many Australian studies.[2]

Discretion is also required when interpreting the results of simple tests of aggregated data because the tests do not take account of the multilevel nature (e.g. students within classes within schools) of the information collected in the study, and, as noted earlier, erroneous conclusions may be drawn. Furthermore, tests of statistical significance are not substitutes for a thorough knowledge of the variables under investigation, nor are they able to establish the practical importance of any differences observed.

Correlations between student background variables and achievement measures

Tables 3.2 and 3.3 provide correlations and level of significance for the student background variables considered to be important for mathematics and science achievement for Populations 1 and 2, respectively. In these tables the correlation of each of the student background variables with ‘Word knowledge’ is also shown for information (even though word knowledge is used later, as a surrogate for verbal ability, in predicting mathematics and science achievement).[ii]

Table 3.2 Correlations between TIMSS Population 1 Student Background Variables and Achievement in Mathematics, Science and Word Knowledge

	Mathematics		**Science**		**Word knowledge**	
Variable label	**r**	***p***	**r**	***p***	**r**	***p***
Student’s gender	.00		-.03	**	.05	***
Student born in Australia	.00		-.02		-.02	
Speak English at home	.09	***	***.16***	***	***.13***	***
Number of people living in the home	***-.14***	***	***-.17***	***	***-.13***	***
Mother’s occupation	***.22***	***	***.22***	***	***.22***	***
Father’s occupation	***.23***	***	***.24***	***	***.22***	***
Higher of mother’s/father’s occupation	***.27***	***	***.27***	***	***.26***	***
Mother born in Australia	.02		-.01		.00	
Father born in Australia	.00		-.02		-.02	
Number of books in student’s home	***.18***	***	***.21***	***	***.18***	***
Calculator in student’s home	***.27***	***	***.27***	***	***.24***	***
Computer in student’s home	***.16***	***	***.15***	***	***.11***	***
Number of items in student's home	***.27***	***	***.27***	***	***.25***	***

** $p < .01$, *** $p < .001$

i This means that only about 2 per cent of the variability seen in students’ achievement scores can be explained by the variance in family size. Ninety-eight per cent is left to be explained by other variables. Therefore even though the correlation is statistically significant, there is some question as to its practical significance.

ii The Word Knowledge measure was included in the Australian TIMSS questionnaires because of the tendency of the mathematics and science tests to draw on verbal ability.

The variables, ‘higher of mother’s/father’s occupation (both populations) and ‘higher of mother’s/father’s education (Population 2 only as this was not asked in the Population 1 questionnaire) were constructed to reduce the impact of missing data.

For Population 1 students the highest positive correlations can be seen between achievement in mathematics and science and *possessing a calculator*, *total number of possessions in the home* (from a given list) and *higher of parents’ occupations*. *Number of books in the home* and *mother’s occupation* and *father’s occupation* separately[i] were also correlated more highly than the other variables with mathematics and science achievement, and also with verbal ability as measured by word knowledge. There are weaker correlations, shown between achievement in all areas and *family size* (in a negative direction) and with *language background* measured as the extent to which English is spoken at home. Students from larger families and students who spoke a language other than English at home at least some of the time achieved lower scores in all areas than those from smaller families and those who always or almost always spoke English at home.

For Population 2 (as shown in Table 3.3) the highest correlations overall can be seen between achievement in mathematics, science and word knowledge and the educational level to which the student aspired. The next highest correlations with mathematics and science achievement were found for higher of mother’s/father’s occupation; higher of mother’s/father’s education level; number of books; and the combined number of possessions in the student’s home. These variables were also significantly correlated with word knowledge, but at a somewhat lower level. Such variables are frequently combined to form a measure of socioeconomic or socio-cultural status.

Table 3.3 Correlations between TIMSS Population 2 Student Background Variables and Achievement in Mathematics, Science and Word Knowledge

	Mathematics		**Science**		**Word knowledge**	
Variable	**r**	***p***	**r**	***p***	**r**	***p***
Student’s gender	-.01		.06	***	-.04	***
Student born in Australia	.02		-.03	**	-.02	*
Speak English at home	.06	***	***.13***	***	***.10***	***
Number of people living in the home	***-.10***	***	***-.11***	***	-.08	***
Mother’s occupation	***.24***	***	***.23***	***	***.17***	***
Father’s occupation	***.29***	***	***.26***	***	***.19***	***
Higher of mother’s/father’s occupation	***.30***	***	***.29***	***	***.20***	***
Mother’s highest education level	***.24***	***	***.23***	***	***.18***	***
Father’s highest education level	***.28***	***	***.26***	***	***.19***	***
Higher of mother’s/father’s education level	***.30***	***	***.28***	***	***.21***	***
Student’s expected highest education level	***.33***	***	***.27***	***	***.27***	***
Mother born in Australia	.01		-.03	**	-.01	
Father born in Australia	.01		-.04	**	-.02	
Number of books in student’s home	***.27***	***	***.28***	***	***.19***	***
Calculator in student’s home	***.13***	***	***.13***	***	.08	***
Computer in student’s home	***.15***	***	***.16***	***	.08	***
Number of items in student's home	***.25***	***	***.23***	***	***.16***	***

* $p < .05$, ** $p < .01$, *** $p < .001$

i These variables considered separately each had about 20 per cent of missing data.

For both Population 1 and Population 2, relatively strong correlations can be seen between achievement measures and the number of books in the home, generally a measure of the "*cultural capital*" of the household. It is interesting to note the very high proportions of Australian students who said they had a calculator in their home (86 per cent at Population 1 and 98 per cent at Population 2) and the moderately high proportions with a computer in the house (63 per cent for Population 1 and 72 per cent for Population 2). The proportions for computers at home were lower only than those for England and Scotland, of all the TIMSS countries.

Correlations between other variables and mathematics and science achievement

This section presents a summary of the correlations obtained between a wide range of other variables included in the Student Questionnaires and achievement in mathematics and science. The topics of the variables are listed in Table 3.4. The correlations computed (Pearson product–moment coefficients) assume linear relationships between the pairs of variables. Some of the correlations obtained were low partly because this assumption was not always valid for the TIMSS data. This shows, for example, in some of the relationships illustrated following the summary table.

Points worthy of note concerning the information in Table 3.4 are that:

- achievement was negatively correlated with whether students had extra lessons in mathematics and science, possibly indicating that it is the weaker students who do extra work outside class (these data might also indicate that there were other factors than time spent in practising mathematics or science that were in effect, such as motivation and interest in the subject, as well as the perceived worth of the subject);
- perceived importance of doing well in mathematics or science had a very low correlation with achievement for the Population 1 students;
- more aspects of perceived importance were asked of the Population 2 students, and most correlations were in the range of around .10 to .20 (though some showed no relationship); highest correlations were for the importance of learning mathematics or science to get one's desired job or to get into a particular post-school course;
- of attributes that students believe are important to do well in mathematics or science, including both internal (natural talent) and external (good luck) factors, the students whose achievement was poor in each of mathematics and science had relatively strong beliefs that good luck is necessary for success, and, to a lesser extent, memorisation of notes also; these results highlight that the students who were not achieving well perhaps looked to external reasons for success, such as "It takes good luck to do well" or "You have to memorise notes to do well";
- a corresponding belief on the part of better achievers that their success was due to hard work was unexpectedly not found at Population 2, and the association was only weak at Population 1;
- for both populations, correlations ranging roughly between .10 and .20 were found between doing well in mathematics or science, liking these subjects and achieving well in them, and negative correlations of the same order indicated that students who found these subjects boring were generally those who were not achieving well; and
- a perception that one usually performed well in mathematics or science was correlated the highest of all of the attitudinal variables with achievement at Population 2, though correlated at a lower level at Population 1.

Table 3.4 Summary of Correlations between Student Questionnaire Items and Achievement in Mathematics and Science

Variable	Population 1	Population 2
Time outside school hours		
Time spent having extra lessons in mathematics or science	Negative; around -.15 to -.20	Negative; around -.10
Time spent studying mathematics or science	Negative; around -.10	Negative; around -.03
Importance of maths/science		
Student thinks important to do well in mathematics or science	Positive; around .02 to .08	Positive; around .14 to .18
Student thinks mother thinks important to do well in mathematics or science	n/a	Positive; around .10 to .17
Beliefs about science		
Student thinks science important in life*	n/a	Positive; around .14
Student would like a job involving science*	n/a	Positive; around .16
Student needs to do well in science to please self*	n/a	Positive; around .16
Beliefs about maths/science		
Student needs to do well in mathematics or science to get desired job	n/a	Positive; around .17 to .23
Student needs to do well in mathematics or science to get into post-school course	n/a	Positive; around .18
Attributes for success		
Belief natural talent needed to do well in mathematics or science	Zero	Negative; around -.10
Belief good luck needed to do well in mathematics or science	Negative; around -.30 to -.33	Negative; around -.25 to -.28
Belief hard work needed to do well in mathematics or science	Positive; around .10	Positive; around zero to .05
Belief memorising notes needed to do well in mathematics or science	Negative; around -.10	Negative; around -.08 to -.15
Enjoyment of maths/science		
Student likes/enjoys learning mathematics or science	Positive; around .08 to .13	Positive; around .20
Student thinks mathematics or science is boring	Negative; around -.18	Negative; around -.15
Student perceives self good at mathematics or science	Positive; around .15 to .27	Positive; around .30 to .36

- *Correlation for corresponding mathematics items around zero

Achievement levels by response category

To conclude this chapter, graphs for a cross-section of the Student Questionnaire variables in relation to achievement[i] are presented to give visual meaning to the relationships summarised in Table 3.4. Some of the graphs shown are for Population 1 and some are for Population 2 (in general, relationships were similar in the two populations). In considering these graphs it is important to remember that the relationships might change when clusters of (for example) student characteristics variables are analysed together, because the variables can interact in ways that do not show in the simple relationships shown in the following figures. How the relationships changed for the Australian TIMSS students, and which relationships, is shown in Chapter 4.

One of the stronger relationships, between achievement and parental occupation, is shown in Figure 3. 1. There is a clear increase in achievement for each increment of the occupations in terms of their social prestige.

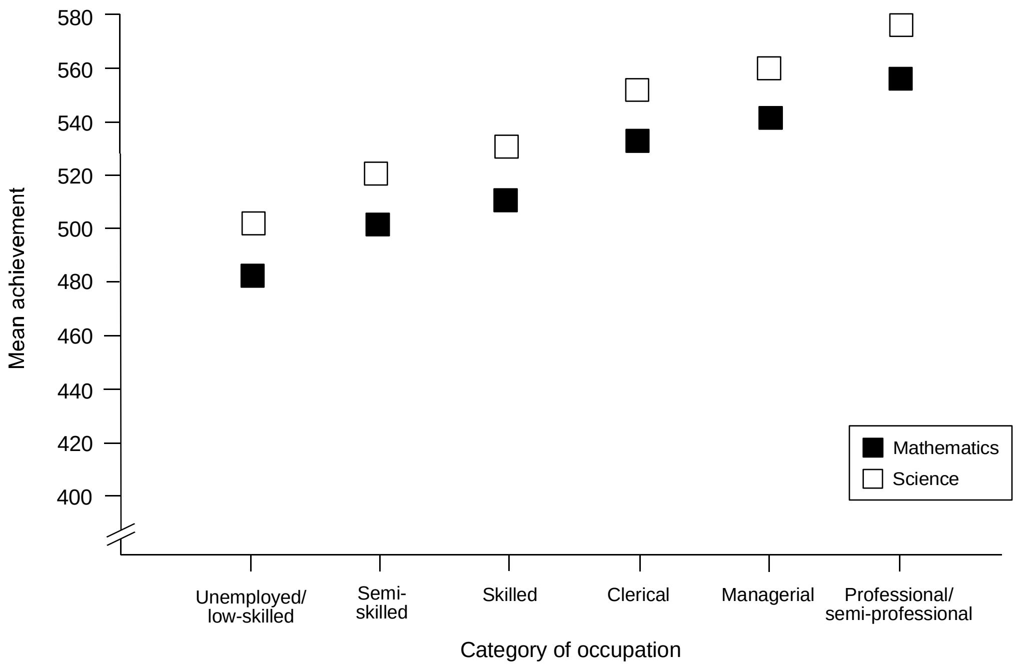

Figure 3.1 Achievement and Parental Occupation, Population 1

A similar degree of relationship is shown in Figure 3.2, for mathematics achievement at Population 1 in relation to the number of possessions, from a list provided, that the students said they had in their homes. These included a dictionary, a computer, the student's own desk for study purposes, the student's own room, and so on, intended to be indicators of family wealth, but also partly of the educational environment of the home. It is not illustrated here, but the relationship of achievement to number of books in the home was very similar to that for possessions.

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i As a reminder, achievement for each of mathematics and science and within each population level was scaled internationally to a mean of 500 and standard deviation of 100.

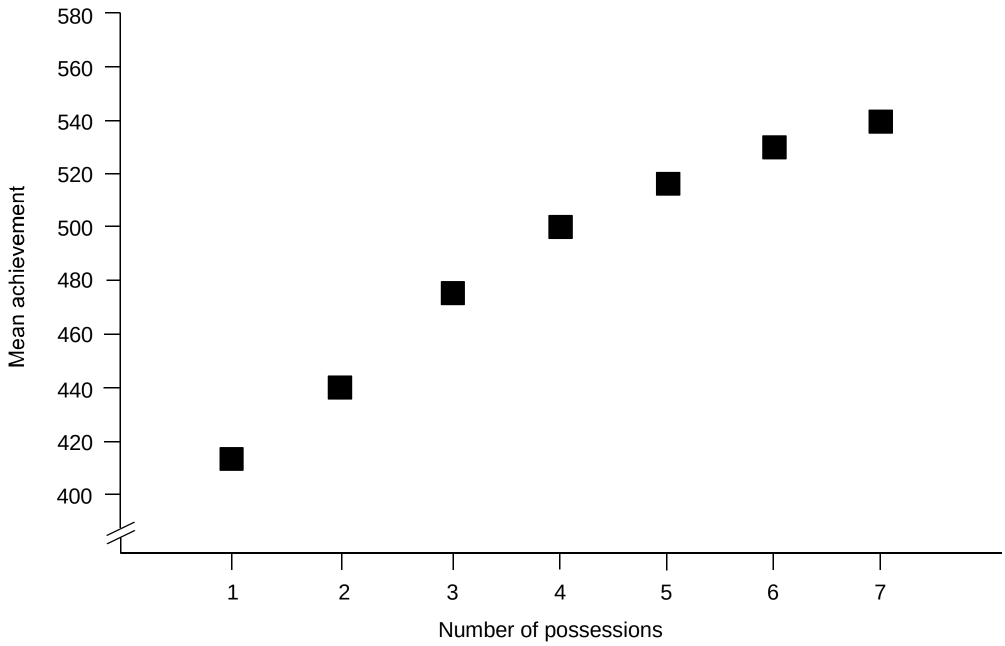


Figure 3.2 Mathematics Achievement and Number of Key Possessions, Population 1

Figure 3.3 shows that achievement clearly increases in association with increased educational qualification of parents. This variable is an indication of the level of education in the student's home environment and also of likely parental expectations for the student's performance.

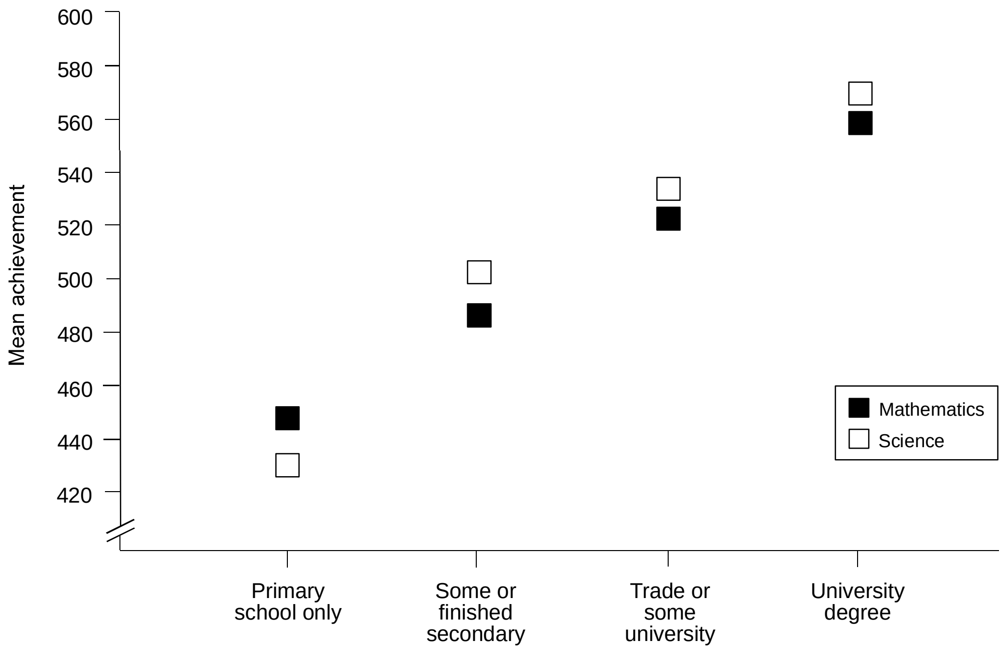


Figure 3.3 Achievement by Parental Education Level, Population 2

Figure 3.4 is the first graph illustrating a negative relationship, at least over part of its range. Family size above five people is associated with lower achievement. Very likely the relationship is due to other factors that go with larger family size rather than with size as such.

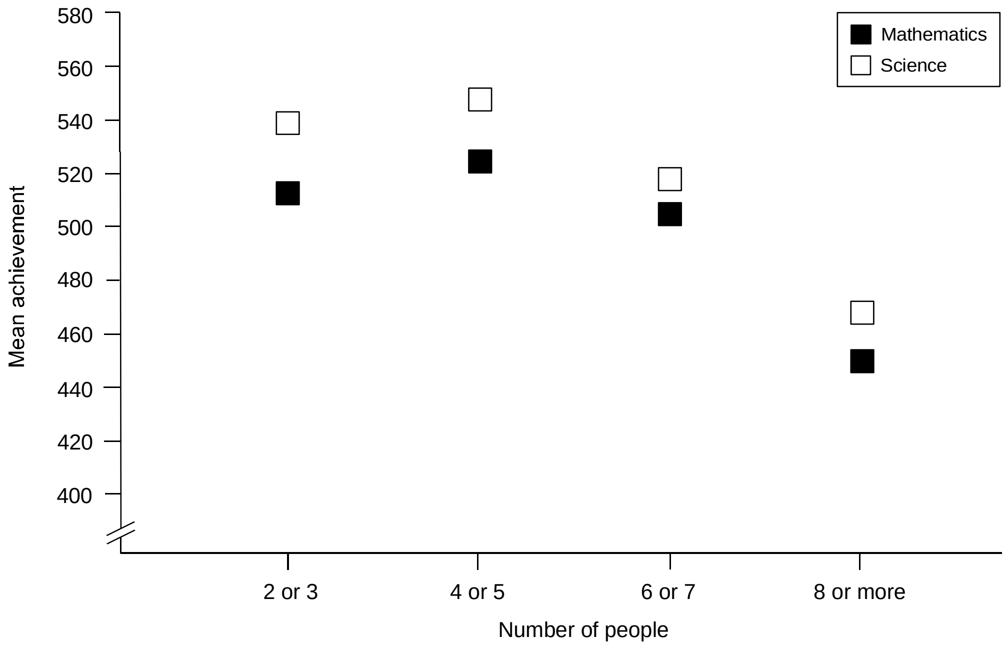


Figure 3.4 Achievement in Relation to Number of People in the Home, Population 1

The next figure, Figure 3.5, shows the relationships at Population 2 of achievement and language background. The background categories represent varying degrees of 'Englishness' of the student's environment, in terms of a combination of where the student and his or her parents were born, and whether English was spoken in the home. It is interesting to see that for science, higher achievement was associated with more English in the student's background throughout the range, whereas for mathematics a higher extent of English beyond 'some' was not associated with improved results.

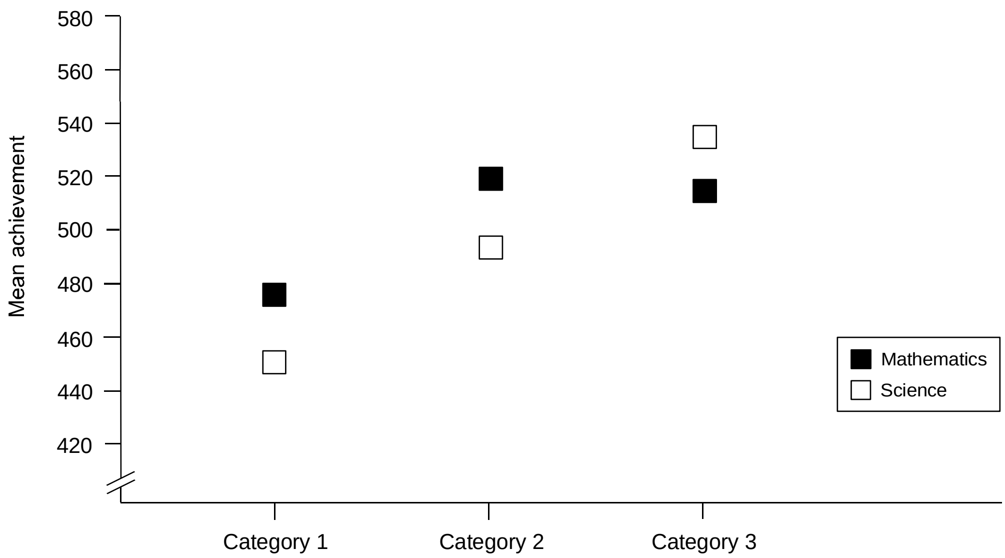


Figure 3.5 Achievement in Relation to Language Background, Population 2

The amount of time spent by Population students (mostly boys) in playing computer games was negatively associated with achievement in both mathematics and science. The same was true at Population 2, but to a slightly lesser extent. Figure 3.6 shows the relationship for mathematics at Population 1.

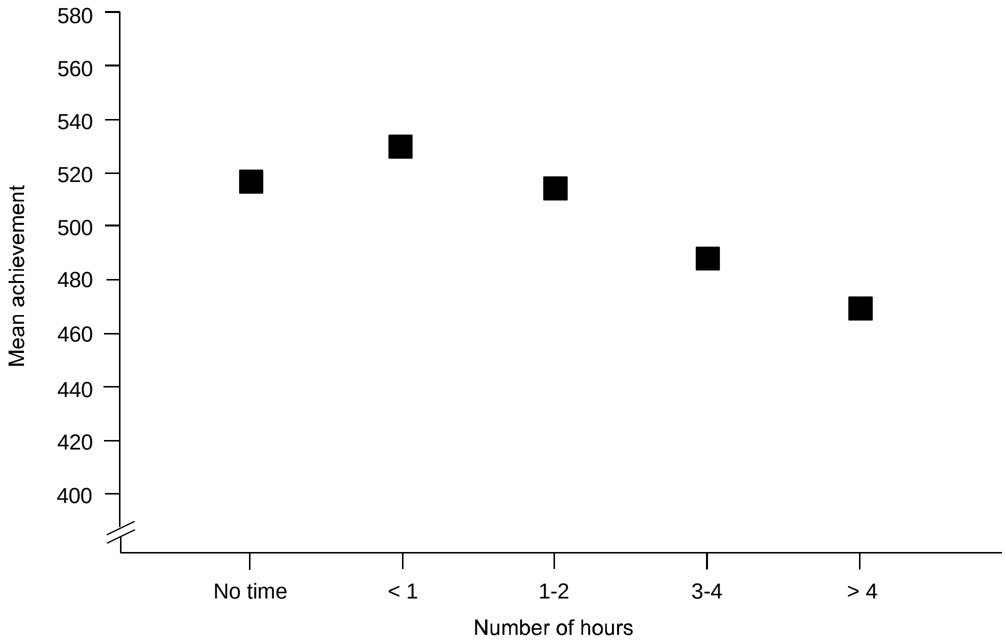


Figure 3.6 Mathematics Achievement and Daily Time Spent Playing Computer Games, Population 1

A similar pattern was also found, however, for time spent studying mathematics and science, shown in Figure 3.7. This suggests that it was most likely the weaker students who were spending more out-of-school time in studying. There was only a small percentage of students in the category claiming to do more than four hours' study a day.

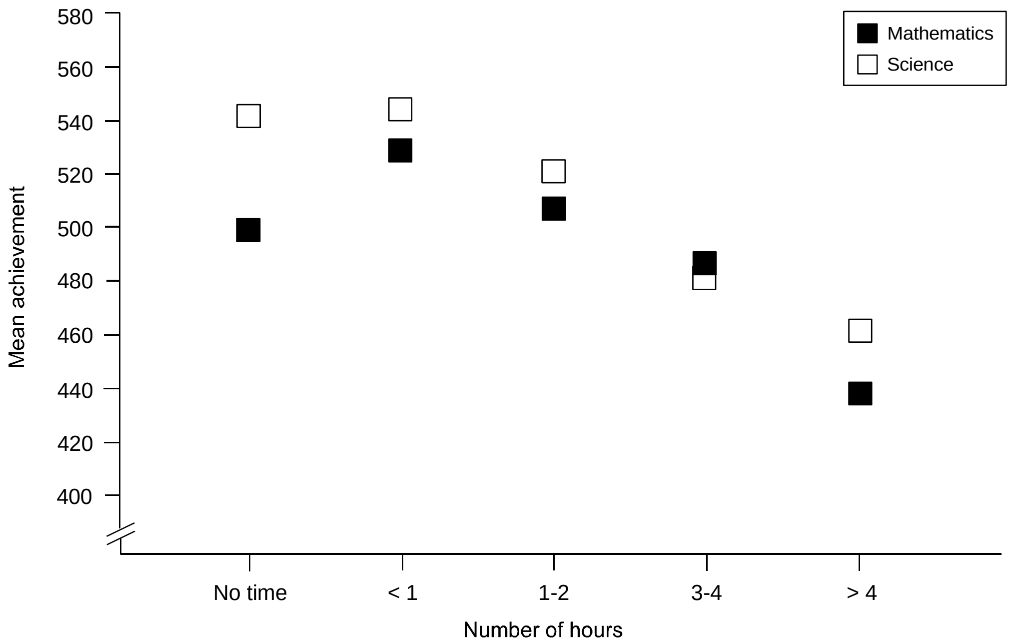


Figure 3.7 Achievement and Hours per day Studying Mathematics/Science, Population 1

The relationship between enjoyment of the subject and achievement is shown for Population 2 mathematics and science in Figure 3.8. There appears to be a stronger relationship between enjoying science and achieving well in it than there appears to be for mathematics.

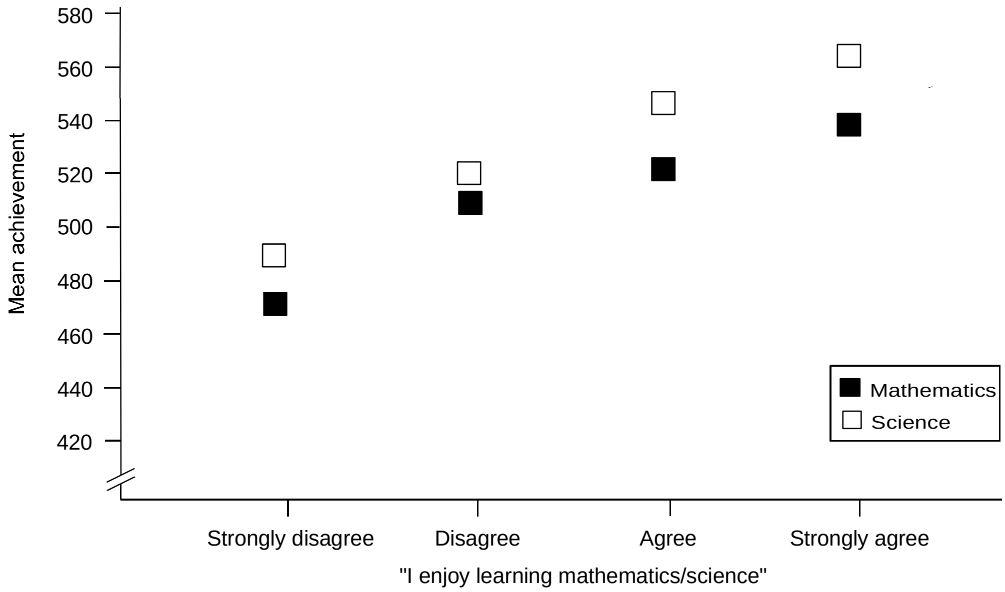


Figure 3.8 Achievement in Relation to Enjoyment of Subject, Population 2

The final relationships illustrated are for the self-estimates of performance in mathematics and science, displayed by gender for each of mathematics and science at Population 1 in Figures 3.9 and 3.10.

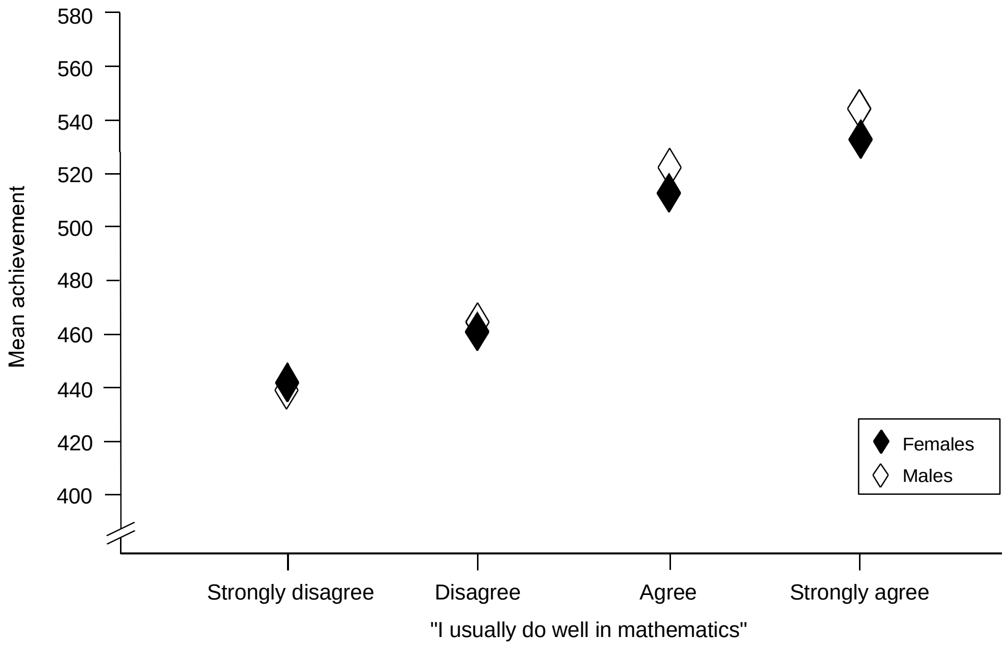


Figure 3.9 Mathematics Achievement in Relation to Self-estimate of Performance, Population 1, by Gender

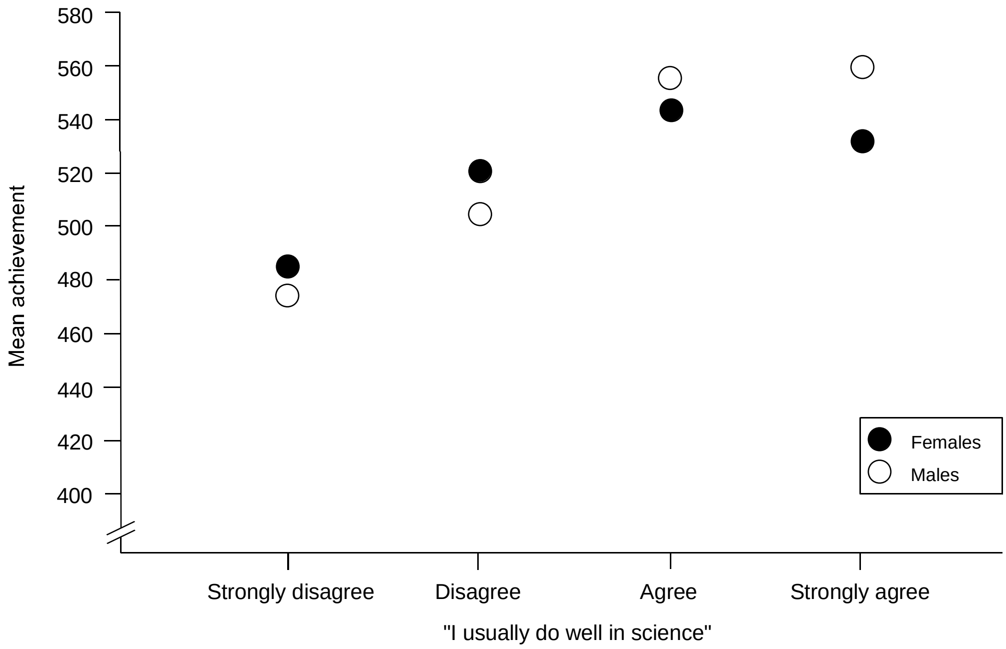


Figure 3.10 Science Achievement in Relation to Self-estimate of Performance, Population 1, by Gender

These graphs are interesting because there is no clear gender effect suggesting a lack of confidence on the part of girls in their ability to do mathematics, at least at mid-primary level. At lower secondary level (Population 2) the girls' self-estimated performance was actually slightly higher than the boys'. A gender effect in this respect is often cited in the research literature, but with girls supposedly *less* confident in their own abilities. The pattern for science illustrated in Figure 3.10 is also interesting. Overall there was no difference in the self-estimates of performance by gender, but the graph suggests a slightly higher confidence among the lower achieving girls than the lower achieving boys, with the reverse occurring for the higher achieving students.

Summary

This chapter examined the relationships between the student-level variables individually and mathematics and science achievement for Population 1 and Population 2 students, with a view to identifying the variables likely to be useful in the secondary analyses. The chapter has also paved the way for the analyses of variables in combination that are described and discussed in the next chapter.

The most significant positive correlations were found between mathematics and science achievement and

- Parents' occupation;
- Parents' education level;
- Number of books in the student's home;
- Total number of key items in the home;
- Students' verbal ability;
- Self-estimates of performance in mathematics and science;
- Belief in the importance of mathematics or science (measured for Population 2 only), particularly to get into the student's desired job or post-secondary school course of study; and
- Attitudes to mathematics and science, measured by liking of the subject, enjoyment in learning it, thinking it is not boring and belief in whether or not it is easy.

For both populations, the most significant negative correlations were between achievement and belief in external factors as the source of success in mathematics and science.

Some typical relationships between the above variables individually and achievement in mathematics and science were shown graphically, to give visual meaning to the degrees of association reported in the tables earlier in the chapter.

Notes

1 For example, M. J. Rosier & D. K. Banks, *The Scientific Literacy of Australian Students: Science Achievement of Students in Australian Primary and Lower Secondary Schools*. Research Monograph No. 39, Australian Council for Educational Research, Melbourne, 1990.

2 J. Ainley, B. Graetz, M. Long & M. Batten, *Socioeconomic Status and School Education*. Australian Council for Educational Research, Melbourne, 1995.

Chapter 4

Multivariate Analysis of the Student Data

The major aim of the secondary analyses of the TIMSS data undertaken for this book was to explore the relationships between achievement in mathematics and science and constructs or factors at student, teacher and school level. These relationships are explored at both the multivariate level (incorporating many variables) and through use of multilevel procedures to cater for the different levels on which the data have been gathered. While there are many different variables in the TIMSS instruments, Bos and Kuiper argued that these instruments 'do not contain well-tested scales necessary to operationalize all important constructs'.[1] Thus exploratory analysis is initially needed to identify scales underlying the variables. This chapter deals with the multivariate analysis of the student-level data.

The IEA research model is based on three levels of curriculum, as discussed in Chapter 1.[2] These three levels are the intended curriculum, the implemented curriculum, and the attained curriculum. In addition to aspects of student background and teacher characteristics, the variables examined in this report are located at the implemented level (teacher variables) and at the attained level (student achievement variables).

The aim at this stage was to propose a model that would examine the effects of student background variables (for example, gender, year level, socioeconomic status), student attitudes (for example, importance of mathematics and science, attitude to mathematics and science), teacher variables (for example, gender, age, years of teaching experience, beliefs about teaching and about mathematics and science), and school variables (for example, size of school) on student achievement in mathematics and science. Figure 4.1 provides an illustration of a proposed model involving these constructs.

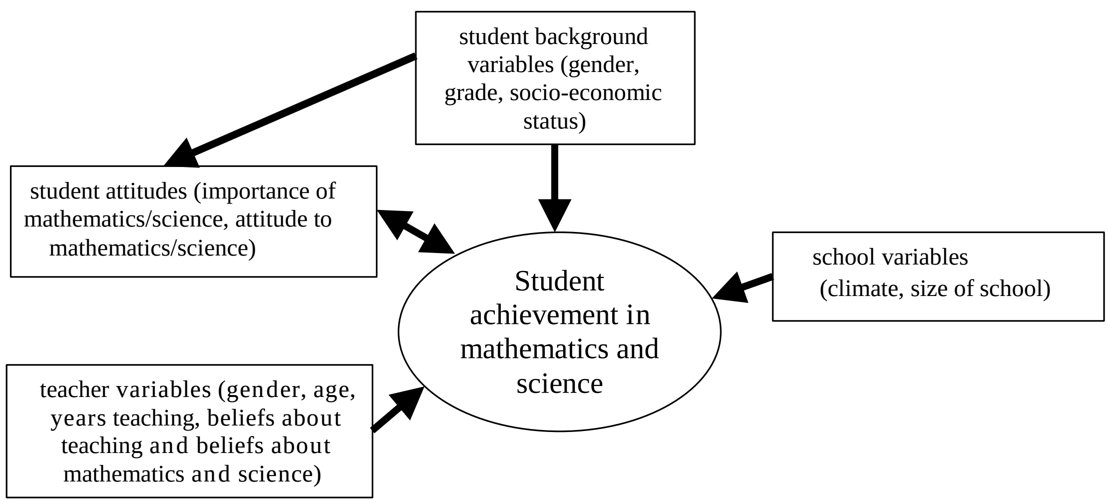


Figure 4.1 Proposed Effect of Student Background, Teacher and School Level Variables on Student Achievement

To inform the construction of composite variables from the large number of individual items in the Student Questionnaire, the results of correlations of some of the most important items with achievement in mathematics and science were included, and in some cases illustrated, in Chapter 3. Following on from the correlational analyses, and as a necessary step for the multilevel analyses reported in Chapter 7, some new student-level variables were created as combinations of the original variables. These constructs are described in the next part of this chapter.

Building constructs

For Population 2 (as shown in Table 3.2) the highest correlations were found between achievement in mathematics, science and word knowledge and the educational level to which the student aspired. The next highest correlations were found between the number of books and the combined number of key possessions in the student's home, as well as by the educational and occupational levels attained by the student's parents, and the indicators of achievement. These variables are frequently combined to form a measure of socioeconomic or socio-cultural status.

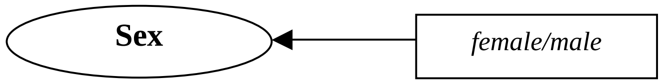
For both Population 1 and Population 2, moderately strong correlations can be seen between achievement measures and the number of books in the home, generally a measure of the '*cultural capital*' of the household. Due to the high proportions of students who had a calculator in the home (86 percent for Population 1 and 98 percent for Population 2) this variable did not show enough variance and so was not included in further analyses. The proportions of students with a computer in the house (63 percent for Population 1 and 72 percent for Population 2) showed more variance, but this variable was also not used in further analyses given the strong likelihood that the proportions in 1994 would not be valid today. It is interesting to note that, when the TIMSS data were collected, Australia was behind only England and Scotland in the numbers of households reported as having a computer.

Construction of factors for the student-level data

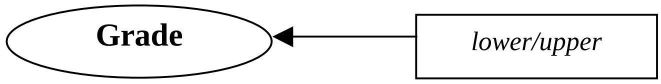
As a result of the examination of the correlations and from analysis of data in other TIMSS related studies, a number of combined variables were developed for multivariate analysis of the student-level data. Several combined variables were developed reflecting the students' perceptions of the importance of mathematics and their own attitude to mathematics. These variables are shown below with the particular TIMSS items that they were composed of. The decision was taken for the analyses reported here to keep the 'cultural capital' aspect separate from the socioeconomic aspect of the students' backgrounds, and hence the 'socio-educational level' (SEL) composite used in the main Population 1 and 2 reports was not persisted with.

BACKGROUND VARIABLES

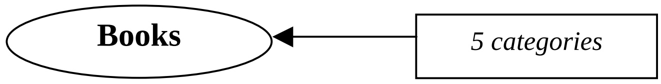
SEX: Student's gender



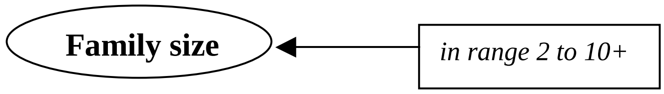
GRADE: Student's year level



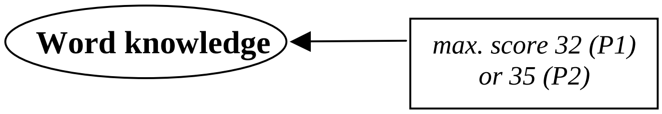
BOOKS: Number of books in student's home. This variable is regarded as representing the "cultural capital" of the family.



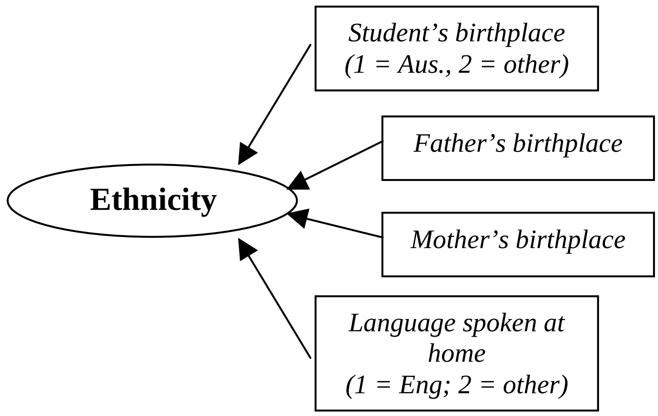
FAMILY SIZE: Number of people living in student's home



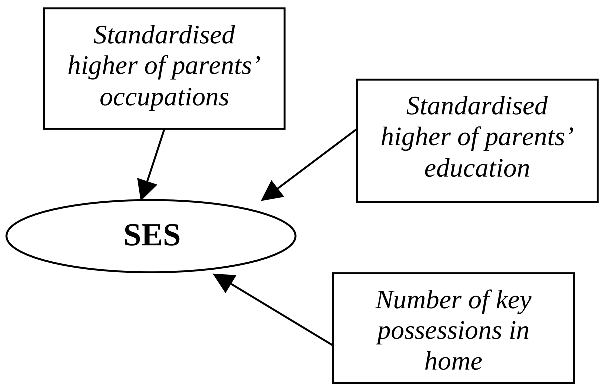
WORD KNOWLEDGE: Verbal ability as measured by the word knowledge test



ETHNICITY: combination of items of student's birthplace, mother and father's birthplaces and language spoken at home.



SOCIOECONOMIC STATUS: This uses the sum of three standardised[i] measures: higher of parents' educational level (Pop. 2 only), higher of parents' occupational level, and the number of key possessions in the home.



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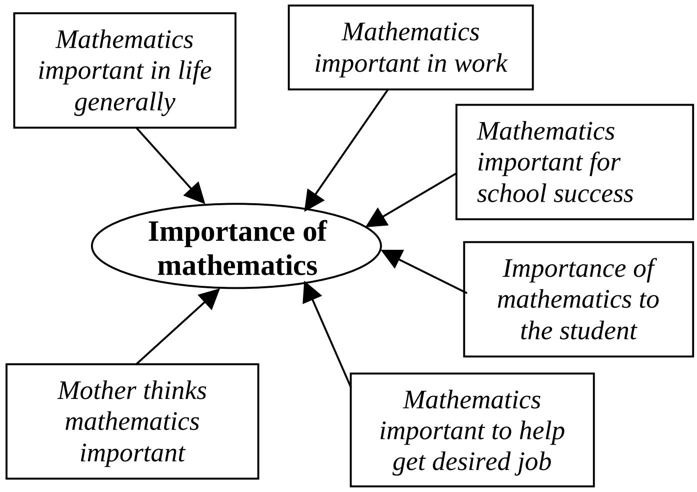
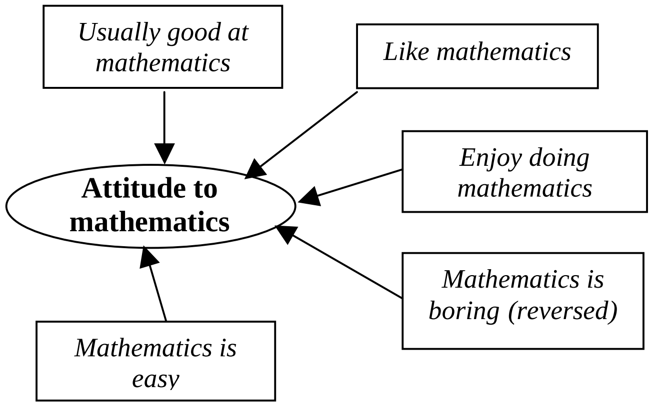
i These variables are standardised because they are measured on different scales. Standardisation adjusts each score so that the new score has a mean of 0 and a standard deviation of 1. In this way the three different scores can be aggregated with each contributing equally to the sum.

MEDIATING VARIABLES

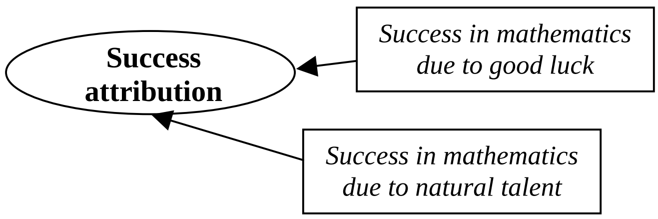
Importance of mathematics: Perceived importance of mathematics (variable defined the same way for science, substituting the responses to the analogous items about science)



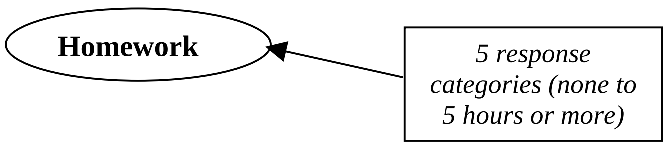
Attitude to mathematics: Students' own attitude to mathematics (variable defined the same way for science, substituting the responses to the analogous items about science)



Success attribution: Tendency to attribute success to factors beyond own control



Homework: On a normal day, time spent before or after school studying mathematics or doing mathematics homework (variable defined the same way for science, substituting the responses to the analogous items about science).



Correlations of student-level composite variables with mathematics and science achievement

The next step was to examine the correlations between the composite constructs outlined above and mathematics and science achievement. These correlations are presented in Table 4.1. Recapping some of the previous discussion, there were no practical gender differences found in either mathematics or science achievement, nor were the factors of ethnicity or family size found to be practically significant. As reported in the main TIMSS reports, Australia was one of only a handful of countries with no significant gender difference in both mathematics and science achievement at Population 2. The only significant gender difference in Australia was found for the lower grade of Population 1, where the boys' performance was better than the girls'. Number of books in the home, as some measure of the 'cultural capital' of the family, was positively correlated with achievement. Word knowledge, used as a surrogate for verbal ability,[3] was found to be moderately highly correlated with achievement, again as would be expected given the verbal nature of much of the TIMSS tests (arising from the desire to present mathematics and science in contexts and to require students to construct some of their responses rather than choose their answer from given alternatives).

Of the variables constructed for these analyses, socioeconomic status of the household provided the strongest correlations with both mathematics and science achievement, followed by the student's attitude towards the respective subjects, particularly for the Population 2 students.

Table 4.1 Summary of Correlations Between Constructed Variables and Mathematics and Science Achievement

Construct	Mathematics achievement		Science achievement	
	Pop. 1	Pop. 2	Pop. 1	Pop. 2
Ethnicity	-.04 ***	.00	-.09 ***	-.07 ***
Socio-economic status	.34 ***	.38 ***	.33 ***	.38 ***
Importance of mathematics	n/a	.11 ***	n/a	
Importance of science				.21 ***
Attitude to mathematics	.19 ***	.27 ***		
Attitude to science			.11 ***	.24 ***
External control: mathematics	-.24 ***	-.24 ***		
External control: science			-.22 ***	-.20 ***

*** $p < .001$

Multivariate analysis

A series of regression analyses was carried out in order to examine the effects of the various background and mediating variables on student achievement in mathematics and science at primary and secondary school levels.[i] These are reported separately for the primary school students and for each of the secondary school subjects. Three levels of variable entry were carried out. These levels are shown in Figure 4.2 for mathematics, but the same model was also applied to the analysis of the science data. For the primary school data the variables

i Regression analyses allow the relative strength of relationship to an outcome (in these cases, student achievement) of several variables acting in conjunction with each other to be estimated.

'importance of mathematics' and 'importance of science', about which only one question was asked in the Student Questionnaire, were not included in these analyses.

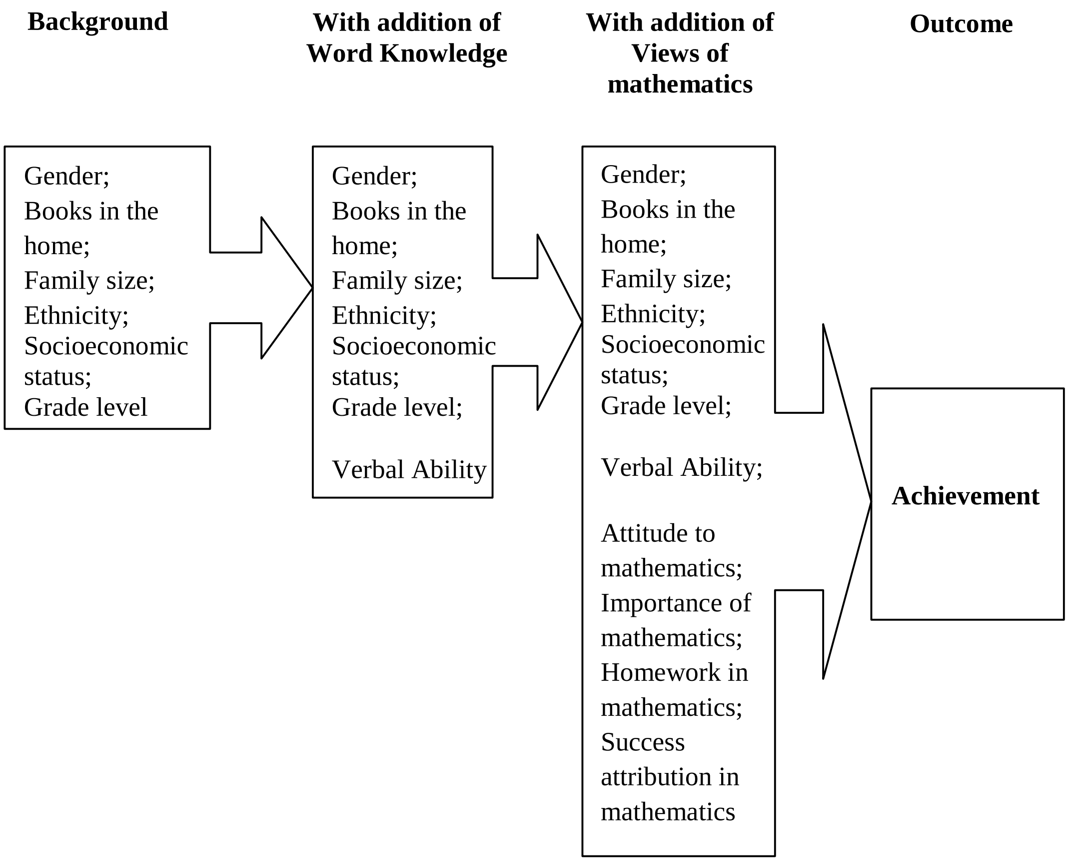


Figure 4.2 The Hypothesised Influence of Student Background, Verbal Ability and Views about Mathematics on Achievement in Mathematics

The model shown in Figure 4.2 hypothesises that student background variables affect student achievement in mathematics (or science) directly as well as indirectly through the students' verbal ability and through their attitudes towards mathematics (or science); their views of the importance of mathematics (science); the amount of homework they do; and whether they attribute their success to factors beyond their own control. Similarly, the effect of verbal ability is hypothesised to be mediated through attitudes to mathematics (science); views of the importance of mathematics (science); the amount of homework students do; and their attribution of success.

Tables 4.2 to 4.5 provide the standardised regression coefficients ('β-weights') for each variable in the theoretical model shown in Figure 4.2, separately for the primary and secondary students and separately for mathematics and science. They also show the values for these coefficients at each stage of the introduction of variables in the proposed causal sequence.[i] Since multiple correlation coefficients (R) showing the extent of relationship

i The β coefficients are an index of the relative importance of variables in relation to each other in predicting levels of a criterion variable – in this case, in predicting mathematics and science achievement. Higher magnitude coefficients (ignoring minus signs) mean the variable is making a greater contribution to the prediction of achievement.

between the variables as a set and the outcome variable are often reported in the literature, the *R* values are included in each table, in addition to the values of R^2.[i]

As a rule of thumb, significant β coefficients ranging between ±0.01 and ±0.09 are considered as having a ‘small’ effect, while coefficients ranging from ±0.10 to ±0.25 are described as having a ‘modest’ effect. Coefficients above ±0.25 are described as having a ‘substantial’ effect. For making within- and between-group comparisons, the value of ±0.04 could be considered as adequate for suggesting that standardised coefficients differ.

Population 1 Mathematics

An examination of the first step of the causal sequence in Table 4.2, for Population 1 mathematics achievement, shows that the first block of variables: gender, grade level, family size, number of books in home, ethnicity and socioeconomic status, explained about 25 per cent of the variance in student achievement. Using the rule of thumb mentioned above, grade level and socioeconomic status can be seen to have had a substantial effect on mathematics achievement, and the number of books in the home a modest effect. In other words, these effects mean that students from a higher grade level and students from a high socioeconomic background achieved at higher levels than those from the lower grade level and lower socioeconomic backgrounds, and that those with a large number of books in the home achieved at a higher level than those with few books.

When the surrogate variable for verbal ability was added to the equation, there was a substantial increase in the amount of variance in student achievement explained. Verbal ability can be seen to have had a substantial direct effect on achievement, and socioeconomic status still had a direct and significant effect, although its effect has decreased substantially. Number of books in the home still had a direct but now weaker effect, as did grade level. In the case of all of the significant variables other than gender, the introduction of the verbal ability variable resulted in a reduction in value of the background variables, suggesting that the effects of these variables were partially relayed through the students’ verbal ability.

The introduction of the third group of variables, representing students’ attitudes to mathematics and the amount of mathematics homework completed, had little influence on the direct effects of the student background variables and the students’ level of verbal ability. Referring to the rule of thumb mentioned on the previous page, the attitude to mathematics variable exercised a modest direct effect on the outcome variable, as did the tendency to attribute success to factors beyond the individual’s control. The effect of the latter was in a negative direction – students with this tendency had lower achievement than their colleagues. There was an increase again in the amount of variance explained by this model. Socioeconomic status and grade level still exerted a modest effect on achievement; verbal ability a substantial effect; and all other significant variables a small effect.

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i The R^2 values are also commonly reported in the literature, and are used to show the proportion of variance in the outcome (‘criterion’) variable that can be ‘explained’, in a statistical sense, by the antecedent (‘predictor’) variables; for example, an R^2 value of 0.40 means that 40 per cent of the variance in achievement can be accounted for by the variables in the predictor set.

Table 4.2 Results of Regression Analysis for Mathematics, Population 1

	Step 1		***Step 2***		***Step 3***	
Variable	*β*	***p***	*β*	***p***	*β*	***p***
Gender	-.01		-.03	***	-.03	***
Grade	.36	***	.24	***	.24	***
Family size	-.07	***	-.03	***	-.02	**
Books in home	.12	***	.06	***	.06	***
Ethnicity	.01		.02	**	.02	*
Socioeconomic status	.27	***	.16	***	.14	***
Word knowledge score			.48	***	.44	***
Attitude to mathematics					.19	***
Homework, mathematics					-.06	***
External attribution, maths					-.13	***
R	.50		.66		.69	
R^2	.25		.44		.47	

* $p < .05$; ** $p < .01$; *** $p < .001$

Population 1 Science

Table 4.3 shows the results of the regression analyses for the Population 1 science data. The first block of variables: gender, grade level, family size, number of books in home, ethnicity and socioeconomic status, explained about 22 percent of the variance in student achievement. As for mathematics, grade level and socioeconomic status can be seen to have had the most substantial effect on science achievement, particularly grade level, and the number of books in the home a modest effect. A significant negative effect occurred for family size. In other words, just as they did for Population 1 mathematics, these effects mean that students from a higher grade level and students from a high socioeconomic background achieved at higher levels than those from lower socioeconomic backgrounds, and that those with a large number of books in the home achieved at a higher level than those with few books. The results also indicate that students from larger families tended not to do as well in science as those from smaller families.

Again as for mathematics at this level, when the variable related to verbal ability was added to the equation, the amount of variance in student achievement explained increased substantially. Verbal ability had a substantial direct effect on science achievement, and socioeconomic status still had a direct and significant effect, although its effect again decreased and was lower than for mathematics. Grade level still exerted a direct modest effect as did socioeconomic status. However in the case of books in the home and family size, the introduction of the verbal ability variable resulted in a reduction in the coefficients (shown under 'Step 2' in the table), suggesting that the effects of these variables are relayed through the students' verbal ability.

The introduction of the third group of variables representing students' attitudes to science and the amount of homework completed added marginally to the proportion of variance explained by the regression. At the primary school level, it seems that attitude to science may have little practical effect on achievement in science, while the effects of the significant background variables remain largely unchanged.

Table 4.3 Results of Regression Analysis for Science, Population 1

Variable	Step 1 β	Step 1 *p*	Step 2 β	Step 2 *p*	Step 3 β	Step 3 *p*
Gender	-.04	**	-.06	***	-.07	***
Grade	.29	***	.17	***	.17	***
Family size	-.12	***	-.07	***	-.06	**
Books in home	.14	***	.09	***	.08	***
Ethnicity	-.04	**	-.03	***	-.03	***
Socioeconomic status	.25	***	.14	***	.12	***
Word knowledge score			.48	***	.45	***
Attitude to science					.11	***
Homework, science					-.06	***
External attribution, science					-.11	***
R	.47		.62		.64	
R^2	.22		.39		.41	

** $p < .01$; *** $p < .001$

Population 2 Mathematics

Table 4.4 presents analogous results of regression analyses to those in Tables 4.2 and 4.3. This time the block of variables in the first step of the hypothesised causal sequence explained some 20 percent of the variance in student achievement. Socioeconomic status and grade level again had a substantial and modest effect, respectively, on mathematics achievement, and the number of books in the home a modest effect. In non-statistical terms, this first step showed that the students from a high socioeconomic background achieved at higher levels than those from lower socioeconomic backgrounds; those at the higher grade level achieved better than those from the lower grade level; and those with a large number of books in the home tended to achieve (only a modest effect) at a higher level than those with few books.

In the second step, when the variable related to verbal ability was added into the analysis, there was a substantial increase in the amount of variance in student achievement explained, although not quite as much as was seen for the Population 1 students. Verbal ability was again found to have a substantial direct effect on achievement, and socioeconomic status still had a direct and significant effect, although its effect decreased considerably. Socioeconomic status and grade level were still found to have a direct moderate effect, as did number of books in the home. The introduction of the verbal ability variable resulted in a reduction in the contribution of the significant background variables, suggesting that the effects of these variables are relayed through the students' verbal ability.

Table 4.4 Results of Regression Analysis for Mathematics, Population 2

Variable	Step 1 β	Step 1 p	Step 2 β	Step 2 p	Step 3 β	Step 3 p
Gender	-.02	*	-.03	***	-.02	
Grade	.22	***	.17	***	.17	***
Family size	-.01		.01		.01	
Books in home	.17	***	.12	***	.11	***
Ethnicity	.03	**	.04	**	.03	**
Socioeconomic status	.30	***	.22	***	.20	***
Word knowledge score			.40	***	.37	***
Attitude to mathematics					.12	***
Importance of mathematics					.10	***
Homework, mathematics					-.02	
External attribution, maths					-.10	***
R	.45		.58		.62	
R^2	.20		.34		.38	

* $p < .05$; ** $p < .01$; *** $p < .001$

The introduction of the third group of variables representing students' attitudes to mathematics, their views of the importance of mathematics, homework completed and success attribution is such that the direct effects of the student background variables and the students' level of verbal ability remained the same while the attitude to mathematics variable exercised a moderate effect on the outcome variable. There was an increase again in the amount of variance explained by this model. Socioeconomic status, grade level, and number of books in the home still exerted a moderate effect on achievement and all other variables had a negligible effect.

From the fully elaborated model, it is apparent that students' attitudes to mathematics and their verbal ability did not entirely account for the variance in students' mathematics achievement. Number of books in the home and socioeconomic status also exerted moderate direct effects on student achievement.

Population 2 Science

Table 4.5 shows the results of the same regression analysis for the Population 2 science data. The first block of variables accounted for about 22 percent of the variance in student achievement. Socioeconomic status once again had a substantial effect on science achievement, even larger than grade level. The number of books in the home again had a modest effect. A smaller but significant effect occurred for gender, the direction of the effect indicating that the boys achieved at a higher level in science than the girls. It is interesting to note that, when gender was considered as a single factor in relation to achievement, there was no significant difference in performance. The same pattern as resulted from the other three analyses also emerged here, in that students from a high socioeconomic background achieved at higher levels than those from lower socioeconomic backgrounds, those at the higher grade level achieve at a higher level than those at the lower grade level, and that those with a large number of books in the home achieved at a higher level than those with few books.

Table 4.5 Results of Regression Analysis for Science, Population 2

	Step 1		*Step 2*		*Step 3*	
Variable	β	***p***	β	***p***	β	***p***
Gender	-.10	***	-.12	***	-.12	***
Grade	.23	***	.17	***	.17	***
Family size	-.05	***	-.03	***	-.03	**
Books in home	.18	***	.13	***	.12	***
Ethnicity	-.03	**	-.02	**	-.03	**
Socioeconomic status	.29	***	.20	***	.19	***
Word knowledge score			.43	***	.41	***
Attitude to science					.06	***
Importance of science					.03	**
Homework, science					-.01	
External attribution, science					-.08	***
R	.47		.62		.62	
R^2	.21		.38		.39	

** $p < .01$; *** $p < .001$

When the variable related to verbal ability was added, the amount of variance explained in student achievement increased substantially. Verbal ability again had a substantial direct effect on achievement, even larger than for mathematics. Socioeconomic status still had a direct and significant effect, although this effect again decreased and was slightly lower than for mathematics. Grade level and number of books in the home still had a direct modest effect. However in the case of the effects of books in the home and grade level, the introduction of the verbal ability variable resulted in reductions in effect, suggesting that the effects of these variables are relayed through the students' verbal ability.

The introduction of the third group of variables representing students' attitudes to science, the importance of science, homework completed and attribution of success did not improve the prediction of achievement and the direct effects of the student background variables and the students' level of verbal ability remained about the same. The attitude to science variable exercised a slight effect on the outcome variable, less than for mathematics. Grade level, socioeconomic status and number of books in the home still exerted a moderate effect.

All regression analyses

Looking at the results from all four of the regression analyses, the overwhelming picture is one of commonality rather than difference in the kinds of findings. Word knowledge, as a surrogate for verbal ability, was an over-ridingly strong predictor of achievement. No doubt this says something about the nature of the TIMSS tests – but modern approaches which advocate teaching mathematics and science with contextual bases mean that merely testing algorithms or abstract algebraic systems would be regarded as not useful. Thus, in the current approaches to teaching and assessment, verbal skills and the ability to communicate one's reasoning in constructed, written responses are essential to making progress at school in most subject areas, including mathematics and science.

The level of relationship found with socio-cultural variables in these analyses is similar to that pervading the research literature in western societies. The relationship of achievement to grade level is also sizeable, and would be a matter of concern if it were not. However, by including grade as a variable in these analyses, a full appreciation of the way the remaining variables interact is masked. For this reason some of the multilevel analyses reported in Chapter 7 were done within the upper grade level only.

Correlations between background variables

Correlations were also examined between the mediating variables for each model, and between the background variables for the two populations. The correlations are presented in Table 4.6. Gender was not correlated with any practical significance with any of the other background variables, nor was family size. As expected, socioeconomic status was correlated both with number of books in the home and with verbal ability.

Table 4.6 Correlations between Student Background Variables, Populations 1 and 2

	Family		WK		Ethnicity		SES	
	Pop. 1	Pop. 2	Pop. 1	Pop. 2	Pop. 1	Pop. 2	Pop. 1	Pop. 2
Gender			.05***	-.04***				
Books in home	-.03**	.00	.20***	.20***	-.15***	-.12***	.31***	.38***
Family size	-	-	-.13***	-.06***	.07***	.05***	-.10***	-.04***
Word Knowledge			-	-	-.07***	-.04***	.30***	.23***
Ethnicity					-	-	-.06***	-.03***

** $p < .01$; *** $p < .001$

The causal directions of the relationships of practical significance (those ≥ .10) for Population 2 shown in this table can be illustrated as in Figure 4.3, with the arrows representing the probable causal direction of the effect. A similar diagram for Population 1 would be slightly more complex, because a path from Word knowledge to Family size would need to be included. The hypothesised direction would be that larger size of the student's family leads to lower Word knowledge scores.

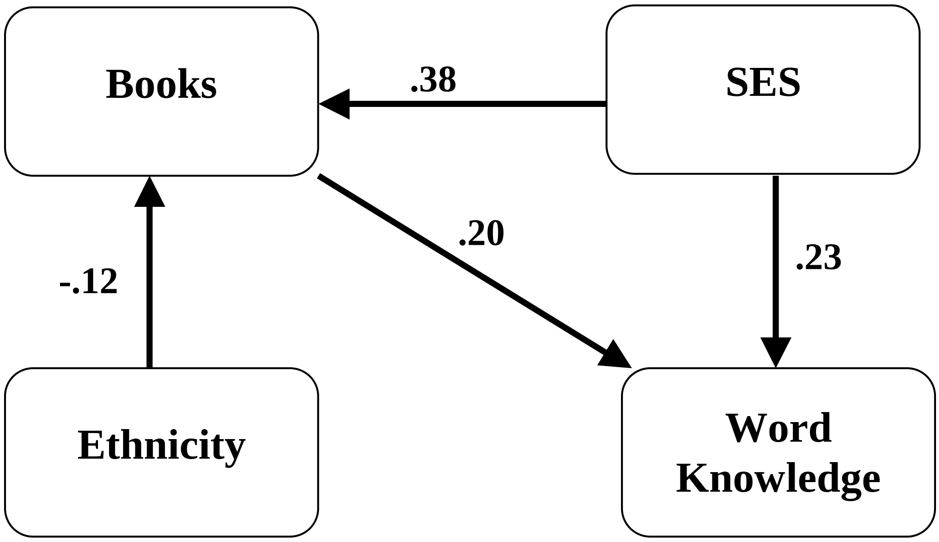


Figure 4.3 Correlations between mediating variables, student-level questionnaire, with hypothesised direction of causation

Correlations between mediating variables

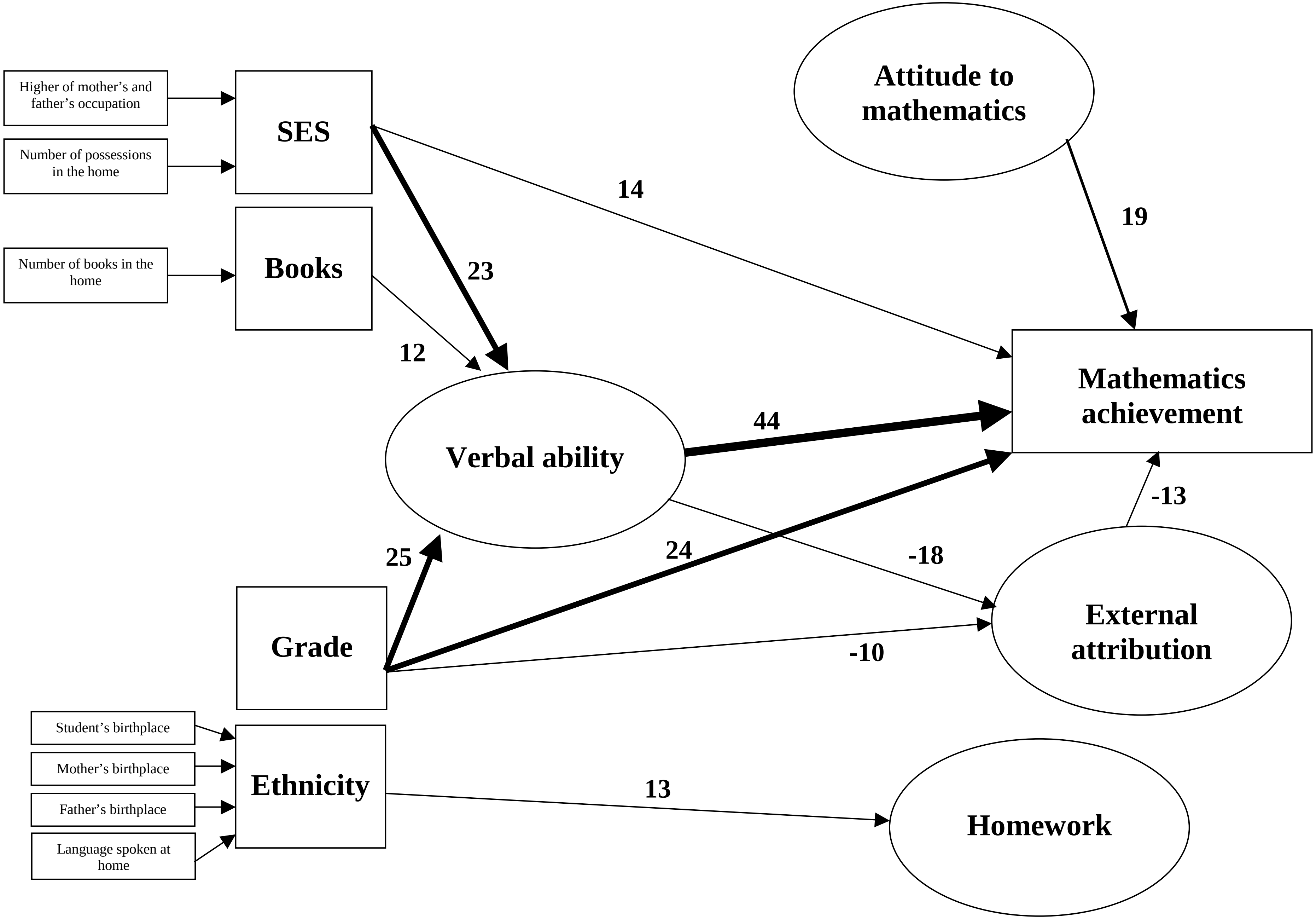
The correlations between the mediating variables for mathematics and science were also examined. Moderately strong correlations were found between students' views about the importance of mathematics and their attitude to mathematics (.50) and between amount of time studying mathematics outside school and views of the importance of mathematics (.20) and attitude to mathematics (.19). All these correlations were found to be significant at the $p < .001$ level.

For science, even larger correlations were found between the students' views of the importance of science and their attitude to science (.60). Again, there were moderate correlations between amount of extra time studying science and both attitude to science (.24) and a view of science as important (.23). All are significant at the p <.001 level.

These relationships can also be expressed in the form of path diagrams, where regression coefficients serve to illustrate the relationships between variables. These diagrams can be seen in Figures 4.4 to 4.7. The diagrams add to the information provided in Tables 4.2 to 4.5. The regression coefficients shown on the arrows are the results of the regression of:

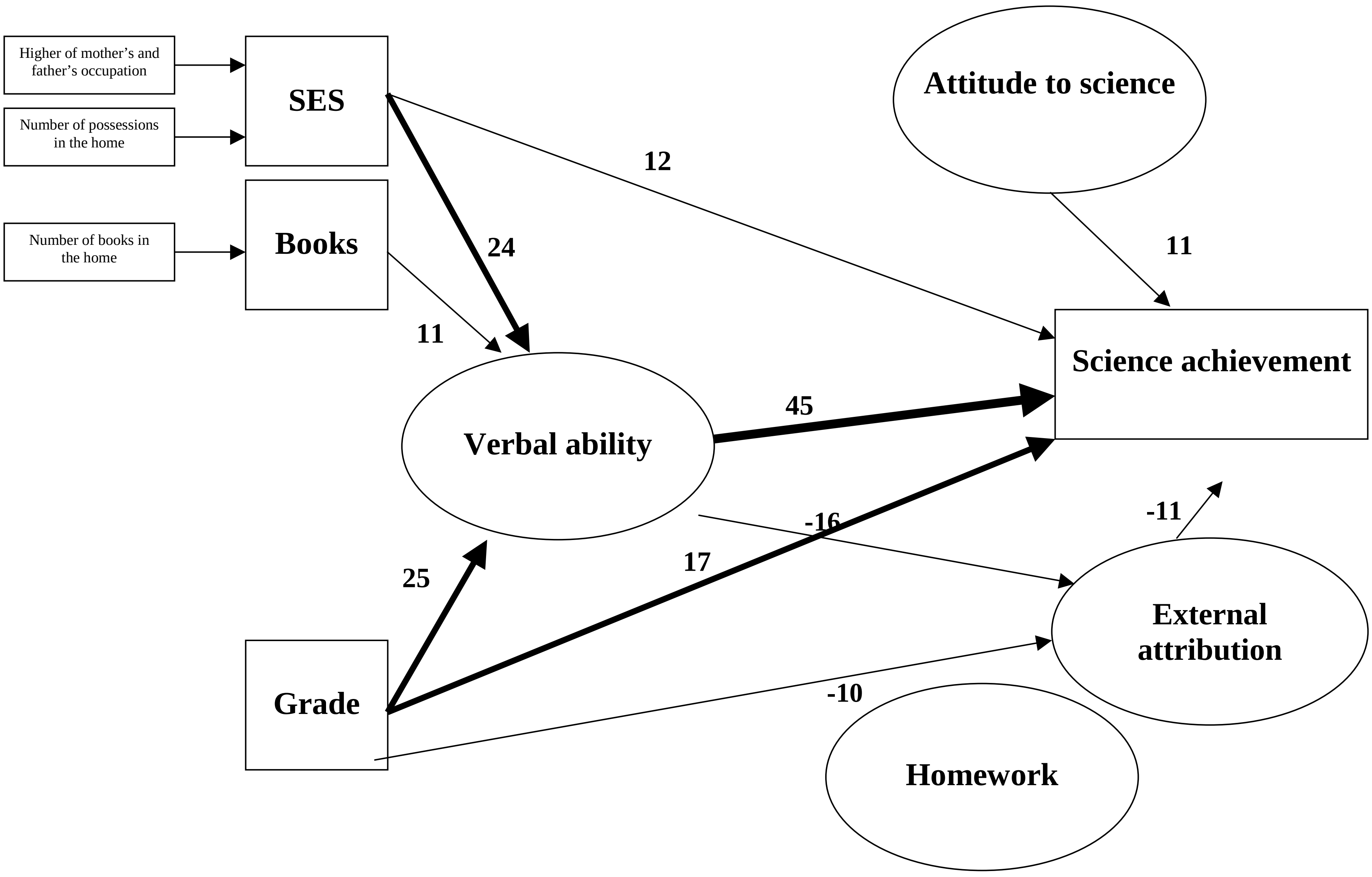
- Achievement onto all variables
- Attitude, Importance (for secondary school students) and Homework individually onto background variables and verbal ability
- Verbal ability onto background variables

Figure 4.4 Path Diagram for Population 1 Mathematics Achievement



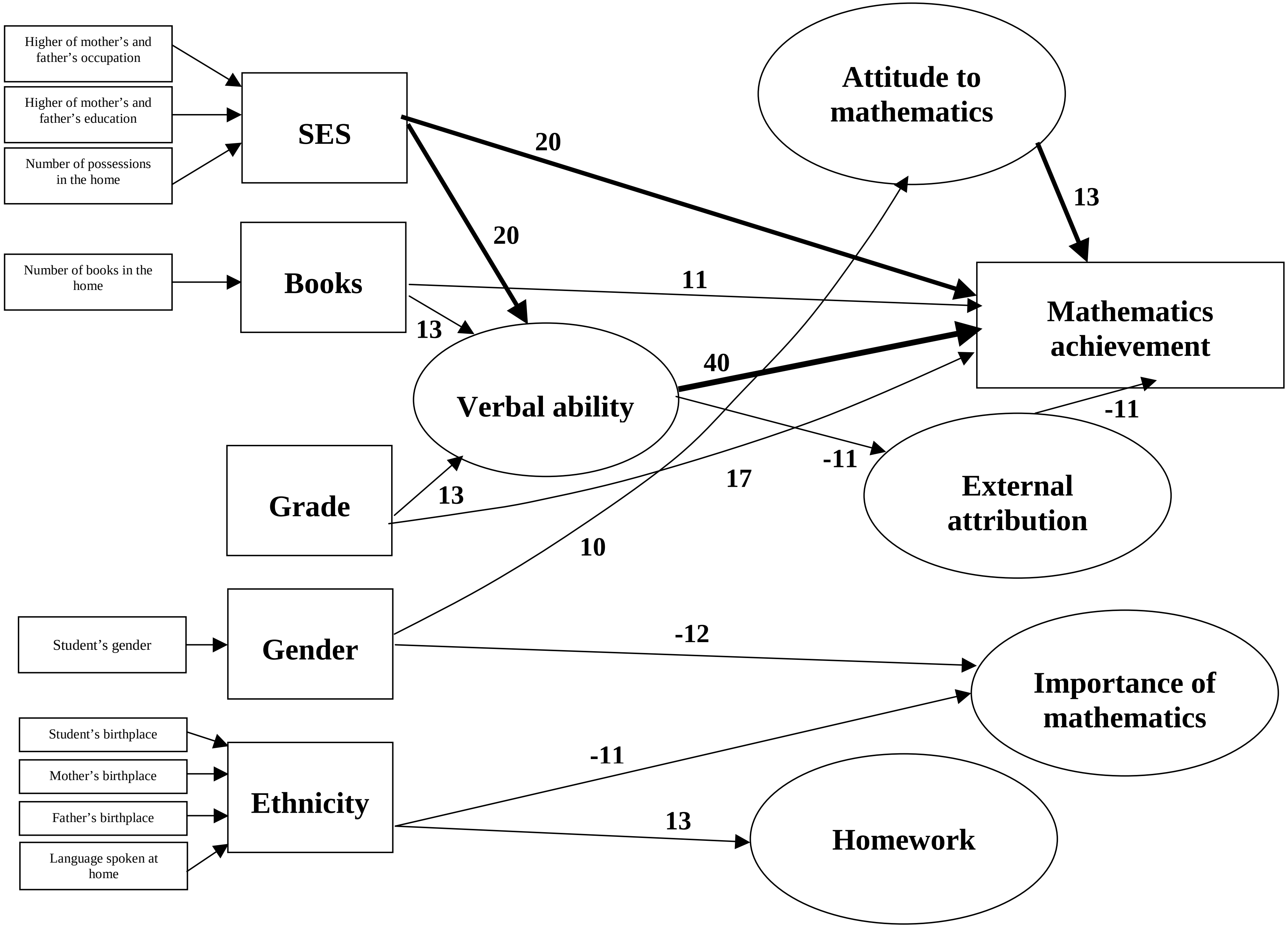
*Note: Only regression coefficients greater than .10 are shown, and decimal points are omitted

Figure 4.5 Path Diagram for Population 1 Science Achievement



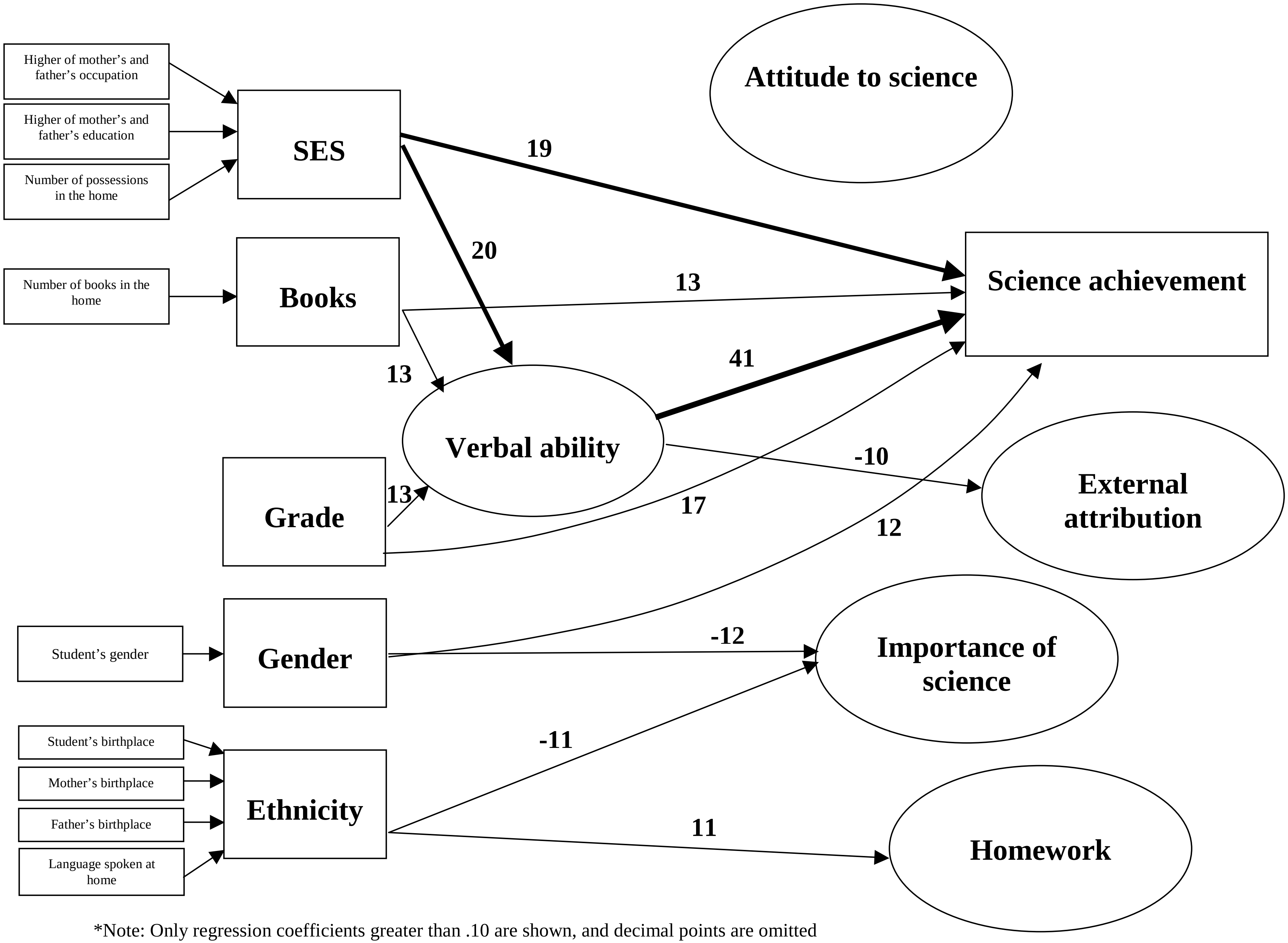
*Note: Only regression coefficients greater than .10 are shown, and decimal points are omitted

Figure 4.6 Path Diagram for Population 2 Mathematics Achievement



*Note: Only regression coefficients greater than .10 are shown, and decimal points are omitted

Figure 4.7 Path Diagram for Population 2 Science Achievement



*Note: Only regression coefficients greater than .10 are shown, and decimal points are omitted

These figures can be summarised by looking at the direct effects of beliefs and attitudes to mathematics and science, the direct effects of the students' verbal ability, and the direct and transmitted effects of the student background variables.

Direct effects of attitude, interest and homework participation

Amount of homework undertaken was not found to be a significant influence on student achievement levels in mathematics and science at either population level. Attitude to mathematics was found to be a significant and quite strong predictor of achievement in mathematics for Population 1 and Population 2, but attitude to science was not similarly predictive of science achievement for either group. Students' views of the importance of mathematics and science were measured with more than a single question only for the Population 2 cohort, and were not found to have a significant effect on either mathematics or science achievement.

Direct effects of verbal ability

There was a direct strong influence of verbal ability on both mathematics and science achievement for both the Population 1 and Population 2 cohorts. This effect appeared to decline slightly between the Population 1 and Population 2 levels.

Effects of background variables

Socioeconomic status and grade level were found to have a direct effect on both mathematics and science achievement for the Population 1 students. For Population 2 mathematics and science, socioeconomic status had a stronger influence on achievement, and while the influence of verbal ability was slightly decreased there was also found to be a direct effect of number of books in the home. As number of books in the home and socioeconomic status were also found to be related to verbal ability, it is probable that there is some confounding between these variables. The only gender effect found was for Population 2 science. This was an interesting finding, given that the analyses by gender alone showed no significant difference in performance.

For Population 1 mathematics, and for Population 2 mathematics and science, ethnicity was found to influence amount of homework undertaken; students from a non-English speaking background were more likely to do a greater amount of mathematics and science homework at these levels of schooling.

For Population 2 mathematics and science, there was a direct effect of gender and of ethnicity on students' belief about the importance of mathematics or science, where boys and students from an English speaking background were more likely to believe in the importance of the particular subject.

Transmitted effects of background variables

The path analysis results also indicate indirect or transmitted effects of background. Primarily, there is a transmitted path between socioeconomic status and achievement in both mathematics and science for both Population 1 and Population 2. High socioeconomic status was associated with verbal ability and in turn with achievement in these areas. Similarly, students in the upper grade levels were found to have a higher verbal ability and higher levels of mathematics and science achievement than students in the lower grade.

Summary

This chapter examined the effects of the student-level variables on mathematics and science achievement for Population 1 and Population 2 students, after reducing the large number of variables in the TIMSS Student Questionnaire to a more manageable number of constructs.

A few variables were considered to be important enough for their effects to be measured independently of other variables in the multivariate analyses, including gender, grade level (whether in the upper or lower grade of the sample), number of books in the home (measured on a 5-category scale), and family size. Verbal ability as measured by the Word Knowledge test was included as a separate student characteristic variable. The student's participation in homework was used as an independent mediating variable.

The composite variables formed to represent background and mediating variables were:

- Ethnicity: comprised of student's birthplace, birthplace of mother and father, and language spoken at home.
- Socioeconomic status: comprised of standardised measures of parents' occupations, parents' level of education, and total number of key possessions in the home (from a given list).
- Importance of mathematics/science (Population 2 only): combination of belief of the importance of mathematics/science to the students' life, their work ambitions, their desired post-school course, to themselves and to their parents.
- Attitude to mathematics/science: whether the student believed that mathematics or science is easy, the extent to which they liked and enjoyed doing it, whether they found it not boring and whether they judged themselves to be good at it.

It was also found that higher achieving students were less likely to believe that it takes good luck to do well in mathematics, and more likely to believe that mathematics is not a subject that requires natural talent or the memorisation of notes.

Multiple regressions of the background and mediating variables on achievement explained 46 percent of the variance for Population 1 mathematics, 36 percent for Population 2 mathematics, 41 percent for Population 1 science and 38 percent for Population 2 science. For both Population 1 and Population 2 mathematics, effects of grade level, number of books in the home, and socioeconomic status were seen to be mediated through verbal ability, while attitude to mathematics had a significant and independent effect on achievement. Importance of mathematics did not have a large effect on achievement. Similar results were seen for science, with the exception being that attitude to science was not found to have a direct effect on science achievement for either population.

It should be noted that none of the background variables was found to have a direct effect on student's attitude to either mathematics or science at either Population 1 or Population 2. This implies that there are other factors at play than those examined in this section of the report, underlining the need for further examination using other factors. The literature reviewed in Chapter 2 has indicated that both school and teacher factors may help to explain differences in student achievement.

In the next chapter, the large number of teacher-level variables from the Teacher Questionnaires are examined for underlying dimensions or factors. By using these factors, the teacher background variables and the relevant student variables identified in the present chapter, the first and second levels of the multilevel analysis can be built. The final level will be the school level variables, which are discussed in Chapter 6.

Notes

[1] Bos, K. & Kuiper, W., Modelling TIMSS data in a European comparative perspective: Exploring influencing factors on achievement in mathematics in Grade 8. *Educational Research and Evaluation*, **5** (2), 1999, pp. 157-179.

[2] D. F. Robitaille, & R. A. Garden, Design of the study, Chapter 3 in D. F. Robitaille & R. A. Garden, (eds), *TIMSS Monograph No. 2: Research Questions & Study Design*. Pacific Educational Press, Vancouver, 1996.

[3] R. L. Thorndike, *Reading Comprehension Education in Fifteen Countries: An Empirical Study*. International Association for the Evaluation of Educational Achievement, Stockholm, 1973.

Chapter 5

Analysis of the Teacher Data

Teachers play an important role in students' learning of mathematics and science, partly because of their pedagogical knowledge, but partly also due to their attitudes and beliefs about teaching their subject matter. Lerman argued in 1993 that 'one of the major themes [arising from his review of the research]… is the significance of teachers' beliefs about mathematics, and about mathematics teaching'.[1] After all, the influences of society on the classroom, cultural influences, the textbooks used and the intended curriculum are all filtered through the teachers' perceptions of their role in students' learning of mathematics and science.

Identifying the teacher level factors for the secondary analyses that are the focus of this book was not straightforward. While the demographic variables such as age and gender clearly needed to be considered and could be derived from single questions, the items posed to teachers about the teaching and learning of mathematics and science needed further probing. An additional stage was needed to explore valid ways for combining these variables into meaningful constructs to use in the multilevel analyses. The first part of this chapter examines aspects of the characteristics of the teachers participating in the study, at each of primary and secondary levels. The second part of the chapter takes and builds on these variables and attempts to draw out the important constructs underlying them.

Teacher characteristics

Australian teachers are an ageing population. The greatest proportion of both the primary level teachers and the secondary level mathematics and science teachers was found to be in the age group from 40 to 49 years. The age distributions of the teachers of the sampled TIMSS classes can be seen in Figure 5.1.

Age

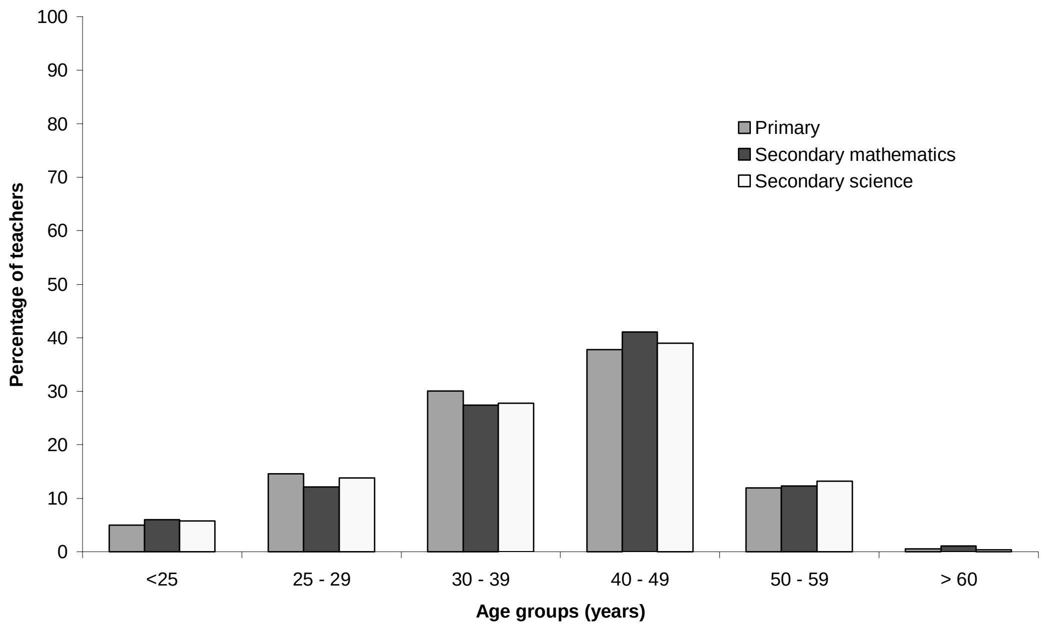


Figure 5.1 Age Distribution by Teaching Level and Area

Age and gender

Overall, females were found to comprise 45 per cent and 44 per cent of the TIMSS secondary mathematics and science teachers, respectively. At the primary level almost three-quarters of the teachers of the sampled TIMSS classes were female.

Figures 5.2 and 5.3 illustrate the age distributions of the TIMSS primary teachers by gender. These figures show that noticeably more male teachers than female teachers were under 40 years of age, though there were more female than male teachers under 30 years of age. It would appear that there are more females than males entering the teaching profession at primary level, with the data showing higher proportions of females in the two youngest age groups.

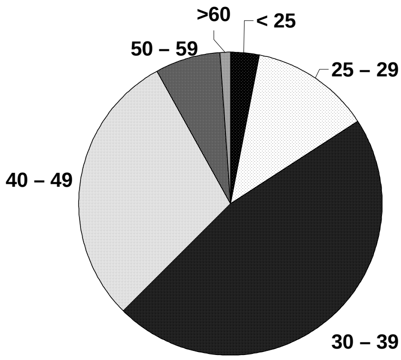


Figure 5.2 Age Groups of Male Primary School Teachers

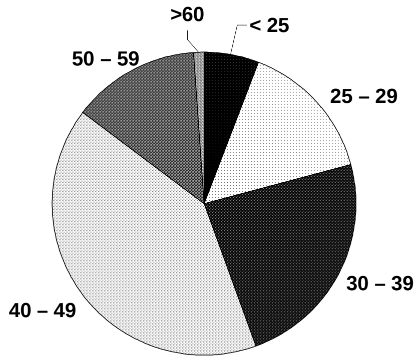


Figure 5.3 Age Groups of Female Primary School Teachers

Figures 5.4 and 5.5 show the age distributions for the male and female secondary mathematics teachers participating in TIMSS, respectively. Again, it is clear from the charts that there was a higher proportion of young females than males, with about a quarter of the females being under 30 years of age but only 11 per cent of the males in this age group. There were larger proportions of males in all other age groups, most noticeably in the 30 to 39 range.

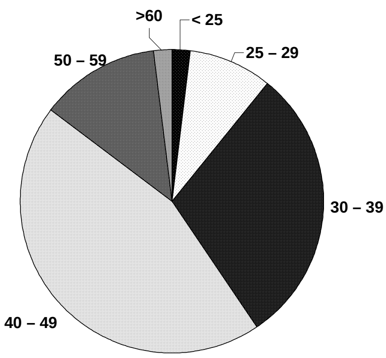


Figure 5.4 Age Groups of Male Secondary Mathematics Teachers

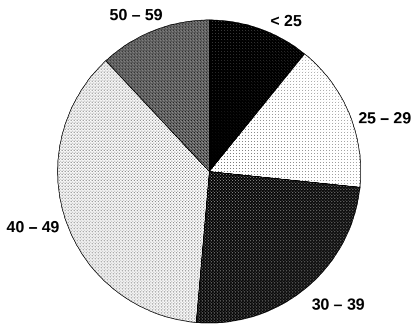


Figure 5.5 Age Groups of Female Secondary Mathematics Teachers

Figures 5.6 and 5.7 present analogous data for the science teachers of the sampled TIMSS students. A very similar pattern to that for mathematics is evident.

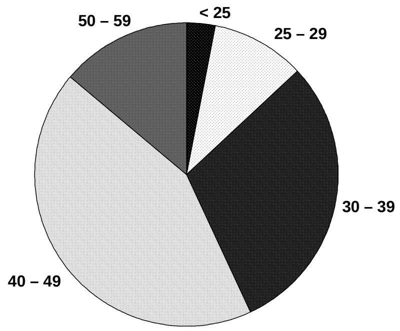


Figure 5.6 Age Groups of Male Secondary Science Teachers

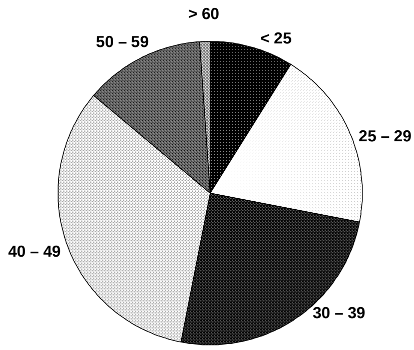


Figure 5.7 Age Groups of Female Secondary Science Teachers

Qualifications

As would be expected, given that academic requirements for teachers have increased over the past few decades, the standard of qualifications of the Australian TIMSS teachers was quite high. This is especially interesting, given that the average age of the teachers in the study was in the mid 40s.

Of the primary school teachers, almost all had either three- or four-year teacher training qualifications, while just over a third held a university degree together with their teacher training qualification. A very small percentage had only two-year training beyond secondary school, all in the older age groups.

At secondary level, half of the mathematics teachers and a few more than half of the science teachers had a Bachelors degree plus a teacher training qualification. Reflecting an increasing pressure on the teaching workforce to obtain higher qualifications, 15 per cent of the primary teachers, 24 per cent of the secondary mathematics teachers and 27 per cent of the secondary science teachers had a post-graduate degree plus teacher training. These percentages were relatively similar for male and female teachers, and an illustration of this for mathematics teachers is presented in Figure 5.8. It can be seen from this graph, however, that the male teachers tended to hold a higher level of qualifications overall than the female teachers.

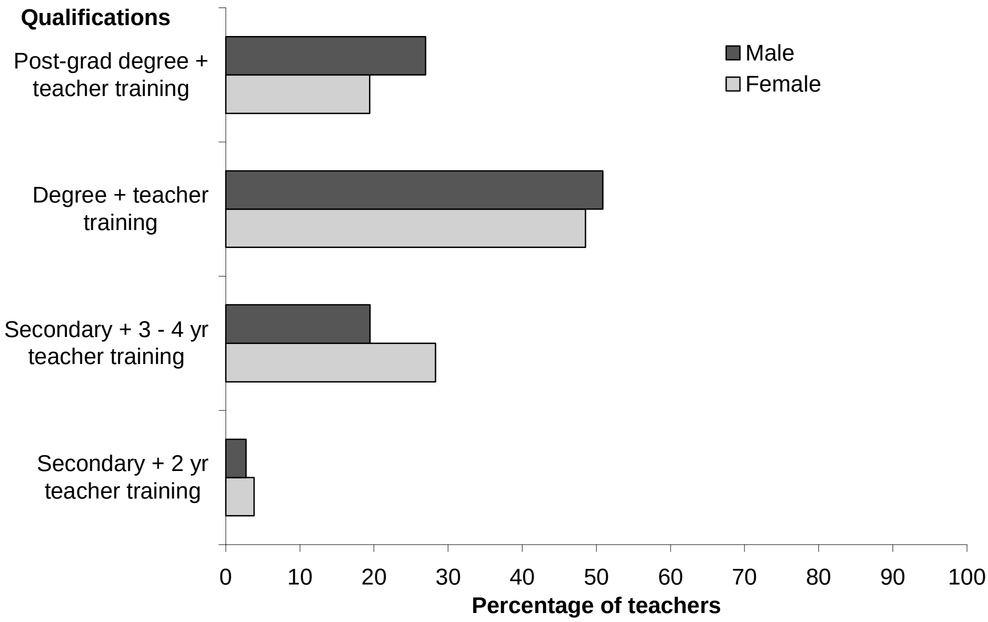


Figure 5.8 Qualifications of the TIMSS Secondary Mathematics Teachers

Student achievement levels

It is of some interest to examine student achievement levels on the TIMSS tests for teachers with different levels of qualification. Figure 5.9 shows Population 2 mathematics achievement levels by teacher qualification and indicates that higher student performance was associated with teachers who had higher levels of qualification. The effect for a higher degree rather than a Bachelors degree appears to taper off somewhat.

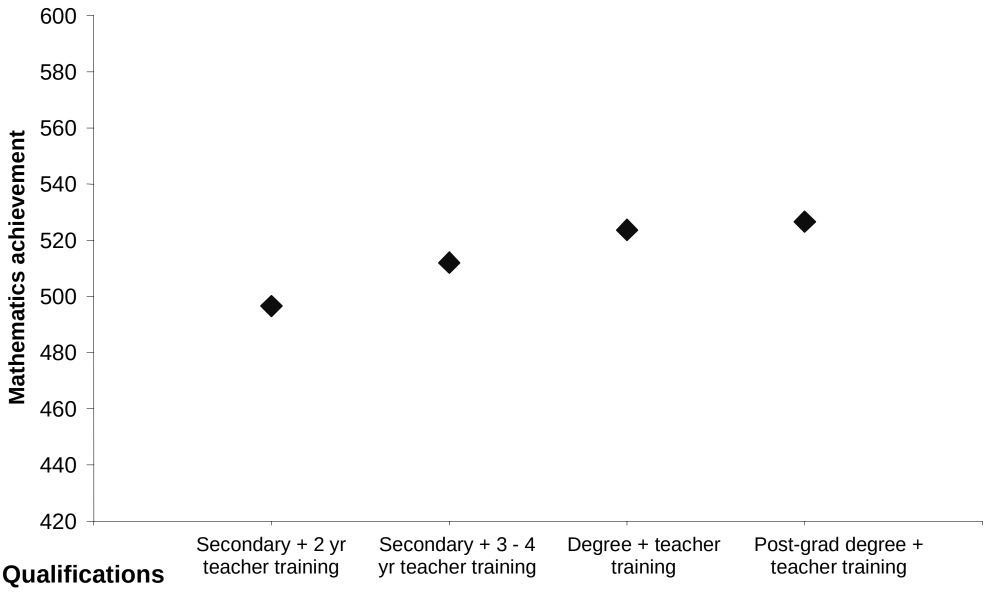


Figure 5.9 Student Achievement by Teacher Qualification Level

The slope of this graph, showing mean achievement increasing from a little below 500 to approximately 530 on the mathematics scale, can be compared with similar presentations of the association of various student characteristics with achievement in Chapter 3.

Teacher attitudes and beliefs

Views on teaching

Teachers were asked several questions pertaining to the choice of teaching as a career and whether they felt that their work was valued. These questions were:

- *Was teaching your first choice as a career when beginning university or teacher training?*
- *Would you change to another career if you had the opportunity?*
- *Do you think that society appreciates your work?*
- *Do you think your students appreciate your work?*

Over 80 per cent of the primary teachers entered the profession as a first choice, and, of these teachers, 43 per cent said they would change jobs if they had the opportunity. Of the primary teachers for whom teaching was not their first choice, over 60 per cent answered 'yes' to this question.

Teaching was the first choice of profession for two-thirds of the secondary mathematics teachers but for only half of the science teachers. However, given the opportunity, just over half of all the secondary teachers surveyed said they would change profession, spread about equally in mathematics and science. Not surprisingly, in mathematics this was more common for those teachers who had chosen teaching as a second or later choice, of whom 62 per cent said they would change careers given the opportunity. For science teachers however the half indicating that they would change careers were spread about equally between those choosing teaching as the first or as a later choice of profession. It is a cause for concern that, of those for whom teaching was their first choice, well over 40 per cent of the mathematics teachers and almost 50 per cent of the science teachers said they would change careers if they could.

Most primary teachers (80 per cent), but a lower percentage of mathematics and science teachers (about 60 per cent in each case) felt that their students appreciated their work. They were much less positive in their perceptions of how the community beyond the boundaries of the school regarded their work, however – around 70 per cent of the secondary teachers and 60 per cent of the primary teachers felt that their work was not appreciated by society in general.

It is of some interest to consider the responses to these items by gender. Figures 5.10 to 5.12 present the breakdown of 'yes' responses by gender for the three groups of teachers. These graphs indicate that it was more likely for the females to have chosen teaching as their career and less likely that they would want to change careers.

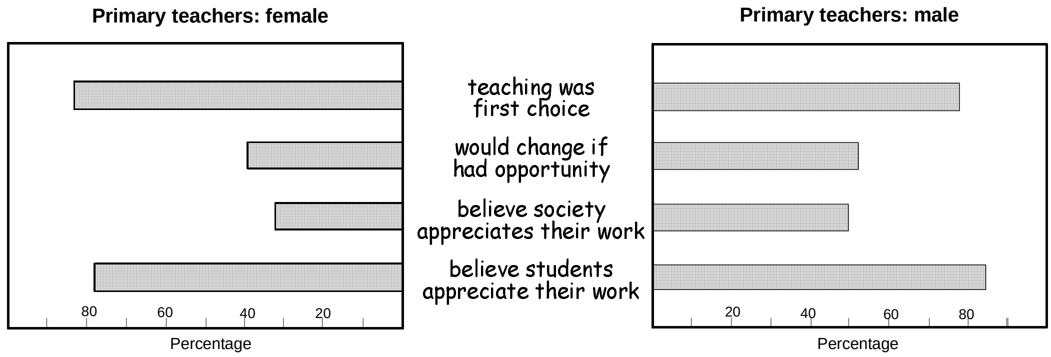


Figure 5.10 Percentage of Primary Teachers Responding 'Yes' to Questions about Teaching, by Gender

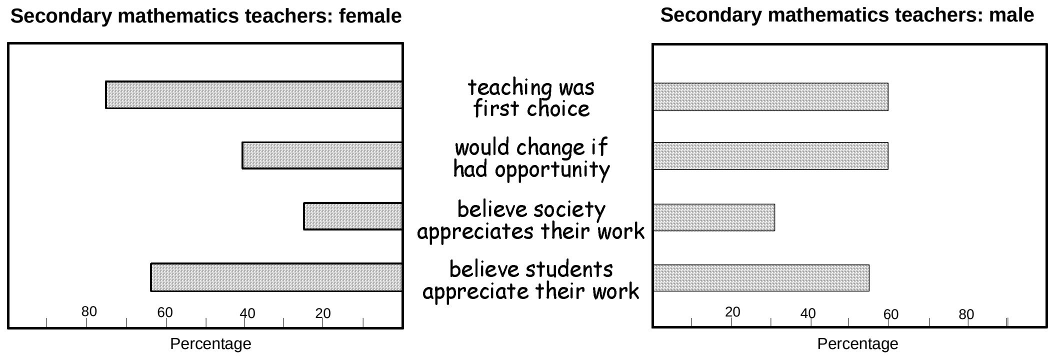


Figure 5.11 Percentage of Secondary Mathematics Teachers Responding 'Yes' to Questions about Teaching, by Gender

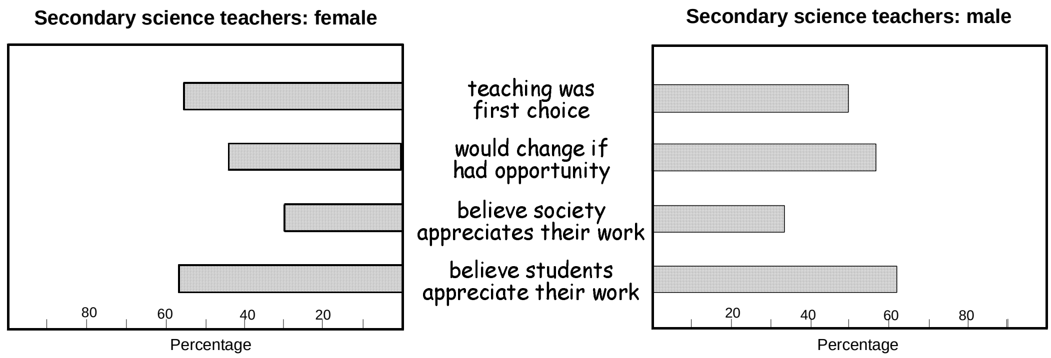


Figure 5.12 Percentage of Secondary Science Teachers Responding 'Yes' to Questions about Teaching, by Gender

The female teachers were less likely than the male teachers to believe that society appreciated their work, a difference that was found to be greater for primary teachers than for secondary teachers. Female secondary mathematics teachers were more likely than their male counterparts to believe that their students were appreciative of their efforts, but for primary teachers and for secondary science teachers this was more often true for the male teachers.

Beliefs about teaching and learning mathematics or science

There were several items in the TIMSS questionnaire that reflected teachers' beliefs about teaching and learning mathematics and science. It was argued by Martin and Kelly in the TIMSS Technical Report, in which the model underlying the questions is discussed in some detail, that:

> the educational research literature has identified a profusion of important teacher characteristics that are related to student performance in mathematics and science. These include the amount of conceptual coherence or focus that teachers build into their lessons (which reflects their own conceptual understanding), how teachers represent the subject matter, the organization and nature of instructional tasks, the patterns of classroom discourse and the types of evaluation.[2]

A selection of these beliefs is examined in the next sections of this chapter. It should be noted that primary school teachers were not asked the same questions about teaching science as were asked of the secondary school science teachers. The main focus of the Population 1 teacher questionnaire was on the teaching of mathematics, and so many of the questions on organisation of instructional tasks and teachers' conceptual beliefs about the teaching of science were not posed to the teachers of this cohort. Reporting about teaching of science in this chapter pertains to secondary level only.

Being good at mathematics or science

Teachers were asked to indicate the level of importance they attached to each of the items shown in Figure 5.13. The percentages provided are for those of the primary and secondary teacher groups who responded that the particular item was 'very important'.

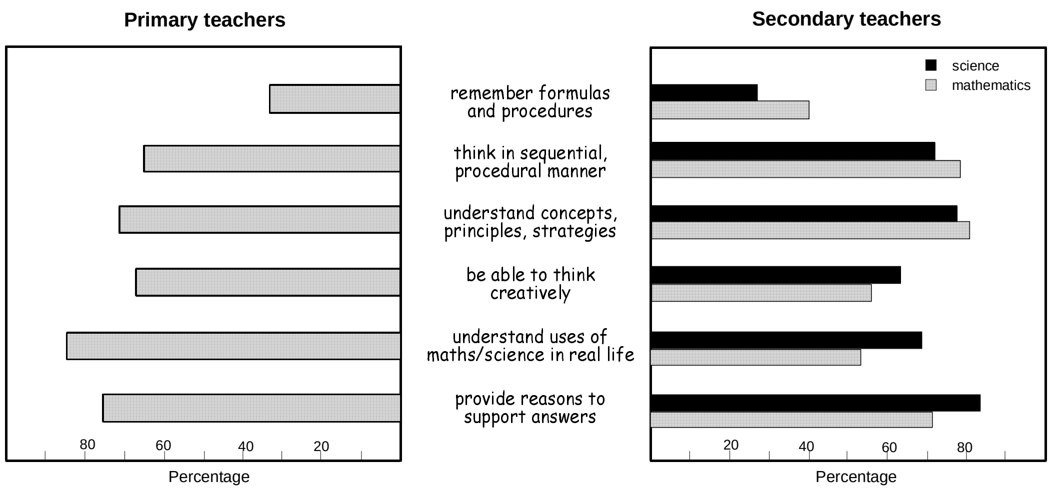


Figure 5.13 Percentages of Teacher Groups Attaching High Importance to Characteristics for 'Being Good' at Mathematics or Science

All the groups of teachers rated the understanding of concepts, principles and strategies as a highly important characteristic of learning mathematics or science. Indicating some differences in the culture of teaching, or perhaps tied in with gender differences at the different teaching levels, almost 80 per cent of the secondary mathematics teachers rated 'thinking in a sequential and procedural manner' as very important compared with 66 per cent of the primary teachers and just over 70 per cent of the science teachers. For the primary teachers, an understanding of how mathematics is used in the real world was seen to be of greatest importance, a factor which was regarded as more important by the science than the mathematics teachers at secondary level.

Greater percentages of the science teachers than the mathematics teachers believed that it is very important for students to be able to provide reasons for their solutions, to be able to think creatively and to understand how their subject (that is, science or mathematics), is used in the real world. These questions were not asked of the primary teachers.

Some of these results were found to be similar for the male and female secondary mathematics teachers, though the female teachers rated thinking in a sequential and procedural manner more strongly than the male teachers did. There were also significant differences in the strength of belief that students should understand how mathematics is used in the real world and that they should be able to provide reasons to support their solutions. For both of these, the female teachers endorsed 'very important' to a greater extent than the male teachers did.

At primary level, the female teachers rated remembering formulas and procedures more highly than the male teachers, but also rated understanding of concepts more highly. The male primary teachers rated being able to think creatively as more important for being good at mathematics.

Having a natural talent for mathematics or science

The mathematics and science teachers were asked how much they agreed or disagreed with the statement that some students have a natural talent for mathematics or science, respectively, and the primary teachers were asked the same question in relation to mathematics.

Figure 5.14, which presents the mathematics and the primary teachers' responses in relation to mathematics, shows that such a belief was held by the large majority of the teachers, with fewer than ten per cent disagreeing to any extent. Secondary mathematics teachers were a little more inclined to agree strongly with this statement than primary teachers were. The percentages for secondary science teachers in relation to science were somewhat lower, with only three quarters agreeing or strongly agreeing with the statement.

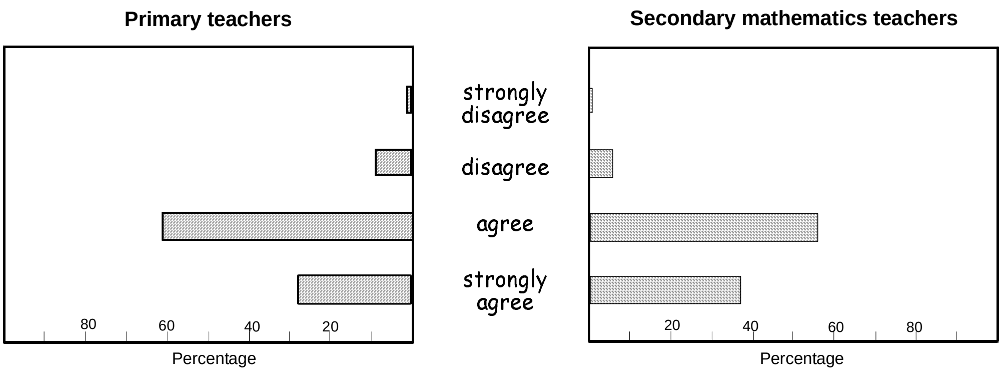


Figure 5.14 Level of Agreement with the Belief that 'Some students have a natural talent for mathematics, others do not'

Beliefs about the nature of mathematics or science

Teachers were asked to respond to a diverse set of items that examined their beliefs about the nature of mathematics and science and how these subjects should be taught. Their responses about the nature of mathematics and science are summarised in this section, in Figure 5.15.

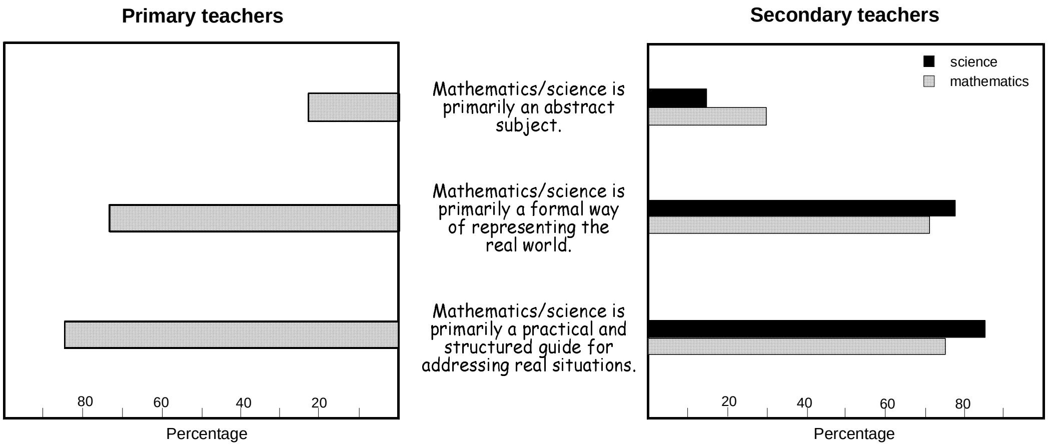


Figure 5.15 Percentages of Teachers Agreeing or Strongly Agreeing about Aspects of the Nature of Mathematics or Science

It is clear that a large majority of the teachers did not regard mathematics and science as primarily abstract subjects. The teachers were of classes at mid primary and lower secondary levels, at which stages early childhood psychologists say that students are mostly not ready to deal with abstract systems. Thus it would appear that the teachers based their beliefs on what they regarded as appropriate for their students – the beliefs indicated here may not necessarily reflect their own perceptions of these subjects as disciplines. The percentages endorsing mathematics or science as related to the real world, as reflected in the second and third statements, were very much higher across all three teacher groups. There was a slightly lower level of congruence here between primary and secondary mathematics teachers, with secondary teachers being slightly less likely to agree that mathematics is a practical and structured guide for addressing real situations. The secondary science teachers expressed an almost identical level of agreement that science is a structured, practical guide as the primary teachers expressed with regard to mathematics.

Beliefs about teaching mathematics or science

As the wording in the mathematics and science teacher questionnaires was slightly different, responses to the items about teaching mathematics or science are examined separately.

The first of these items (Figure 5.16) asked teachers whether they thought that an effective strategy for students having difficulty in mathematics is to give them more practice by themselves during class. Their responses showed that this matter is not as clear-cut as many of the others they were asked about, as both primary and secondary teachers were split fairly evenly for and against this strategy.

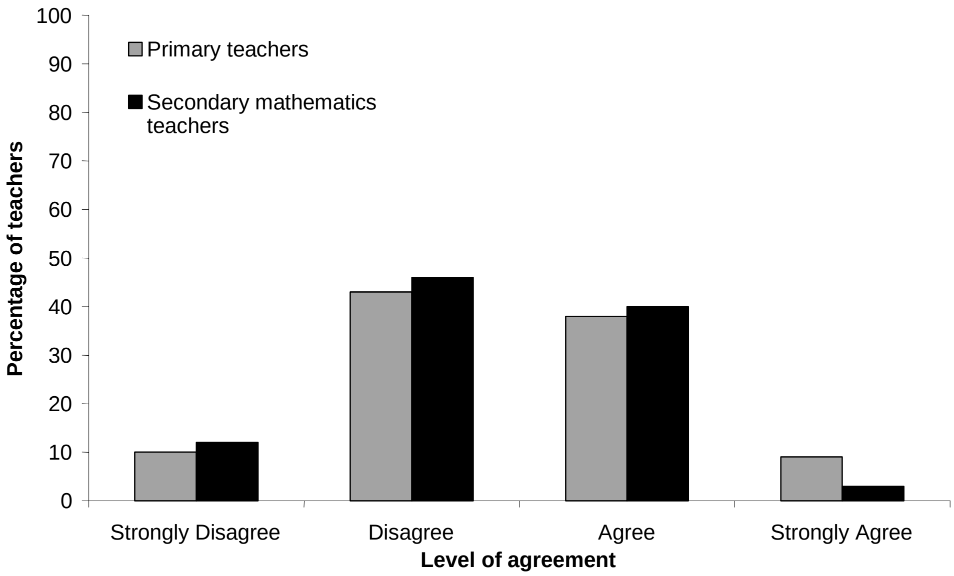


Figure 5.16 Level of Agreement with 'Giving students having difficulty more practice is an effective strategy'

It is unfortunate that the questionnaires did not explore this issue more closely, because there are several questions that could arise. For what reasons did teachers who agreed or disagreed with this statement do so? There could be a number of alternative explanations. Teachers may believe that for some students it may simply be that more practice is needed, especially if the students are prone to be careless in their work – whereas for other students, further or different explanations could be needed. It is clear from the data in Figure 5.16, however, that there are certainly differences in teachers' beliefs on this item, and further exploration will examine its significance on student achievement levels.

Figure 5.17 shows that there was general agreement among the TIMSS teachers that mathematics topics should be taught using more than one representation. The level of agreement was much more emphatic from primary than secondary teachers on this item, perhaps reflecting more diverse abilities of primary school students in mathematics, perhaps related to the more common practice in primary teaching of using concrete representations.

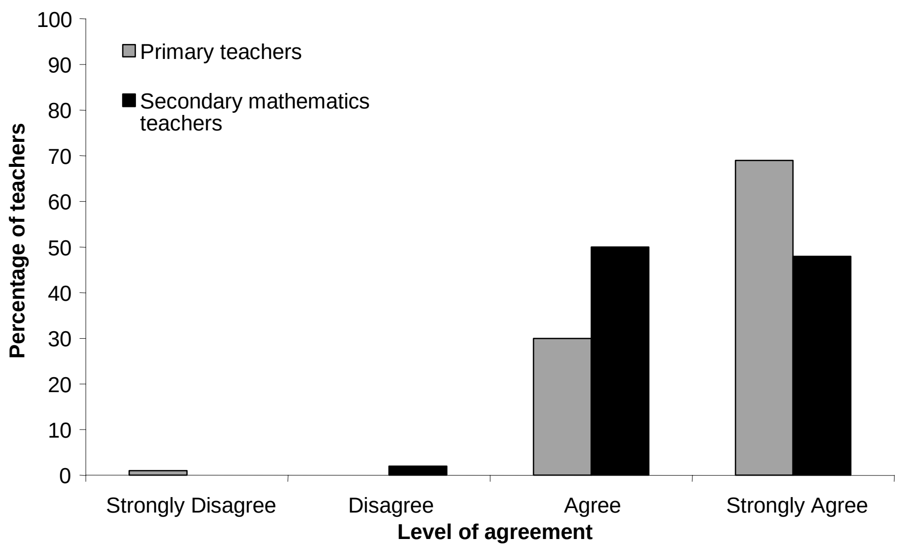


Figure 5.17 Level of Agreement to 'Using more than one representation in teaching a mathematics topic'

While it is encouraging that most teachers surveyed disagreed to some extent with the notion of learning mathematics as sets of rules or algorithms that cover all possibilities, there were still about one in six of both the primary and secondary mathematics teachers who thought that this is the preferable method for teaching or learning mathematics, as shown in Figure 5.18.

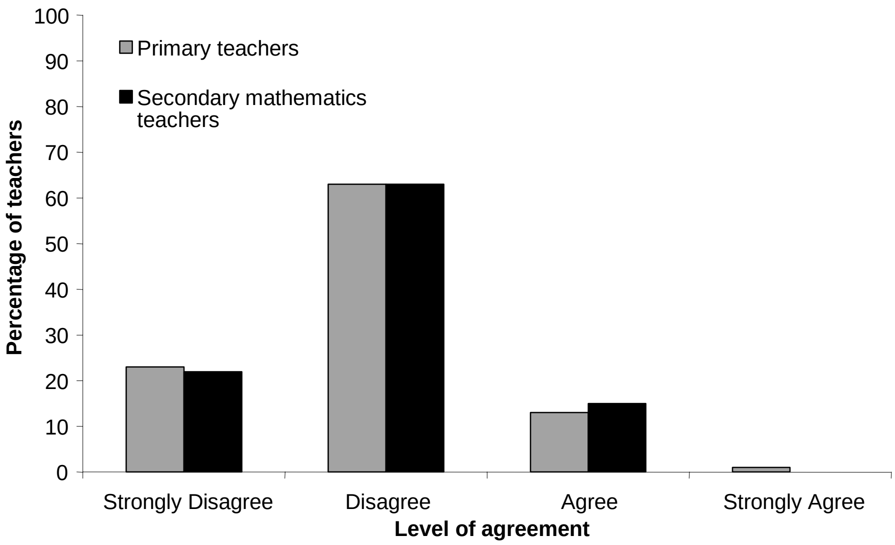


Figure 5.18 Level of Agreement that 'Mathematics should be learned as sets of algorithms or rules that cover all possibilities.'

Again, it is encouraging that most of the teachers also disagreed, many of them strongly, that basic computational skills are sufficient for teaching primary level mathematics. This view was true for both primary and secondary teachers. However Figure 5.19 shows that there were about 15 per cent of primary and about 10 per cent of secondary teachers who did believe that this level of expertise would suffice.

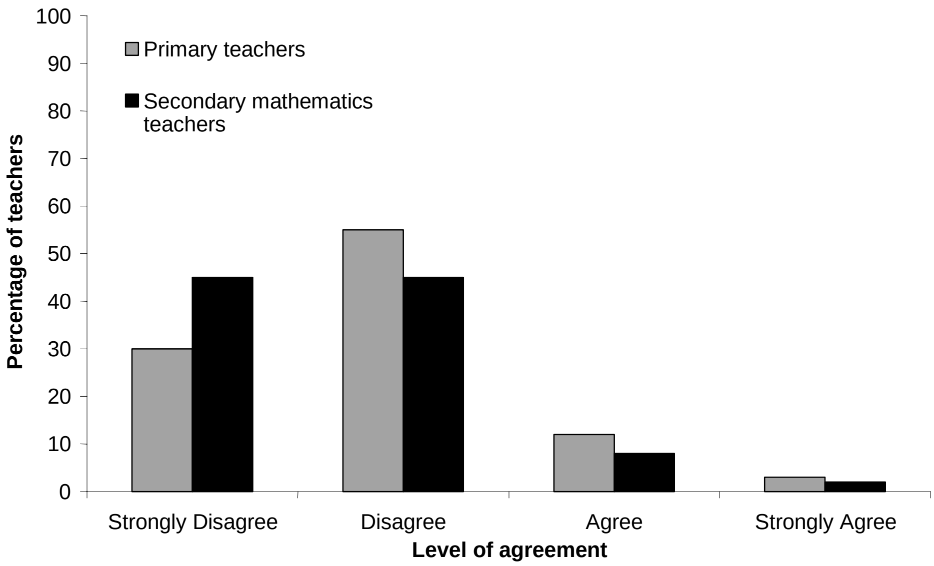


Figure 5.19 Level of Agreement that 'Basic computational skills on the part of the teacher are sufficient for teaching primary school maths.'

The question pertaining to teaching science was not asked of the primary teachers. Table 5.1 shows the statements that were presented to the Population 2 science teachers, and the percentages who agreed or strongly agreed with each statement.

Table 5.1 Extent of Science Teachers' Agreement with Statements about Science Teaching

	% agree/strongly agree
It is important for teachers to give students prescriptive and sequential directions for doing science experiments.	64
Focusing on rules is a bad idea. It gives students the impression that the sciences (physics, chemistry, biology and earth science) are a set of procedures to be memorised.	50
If students get into debates in class about ideas or procedures covering the sciences, it can harm their learning.	5
Students see a science task as the same task when it is represented in two different ways (picture, concrete, material, symbol, etc.).	34

Of interest are the responses to the item about whether the teachers thought it is a good idea to focus on rules. Half of the teachers did think that focusing on rules is a good way of teaching science, despite the negative wording of the question. This is in contrast with the views of the mathematics teachers, with only about 15 per cent agreeing that mathematics should be taught as sets of rules and algorithms.

All the teachers were asked the appropriate version of the question: How much do you agree or disagree with the statement, 'A liking for and understanding of students are essential for teaching mathematics/science.'? Support for this item was highly positive, with 90 per cent of the primary teachers and 92 per cent of the secondary teachers offering their agreement. This could well be not particularly reflective of the subjects of mathematics and science but of the teachers' views in general.

Asking students about specific activities in the mathematics and science classroom

Teachers were asked to indicate the frequency with which they asked students to work using particular methodologies or equipment in the classroom. The responses are presented in Table 5.2 for the mathematics teachers and Table 5.3 for the science teachers. Generally, the data show similar patterns of response. Notable among these is that teachers of both mathematics and science said they asked students on a regular basis to explain the reasoning behind their ideas and that computer use in both subjects was reported to be very limited. As well, in mathematics it was still not common for students to be asked to work on open-ended problems or on problem-solving activities for which there is no obvious solution.

Table 5.2 Percentage Responses to 'In your mathematics lesson, how often do you usually ask students to do the following?'

	Never or almost never	Some lessons	Most lessons	Every lesson
Explain the reasoning behind an idea	2	40	47	11
Represent and analyse relationships using tables, charts or graphs	15	80	5	1
Work on problems for which there is no immediately obvious method of solution	30	66	4	0
Use computers to solve exercises or problems	76	23	1	0
Write equations to represent relationships	16	70	13	1
Practise computational skills	9	40	40	12

Table 5.3 Percentage Responses to 'In your science lesson, how often do you usually ask students to do the following?'

	Never or almost never	Some lessons	Most lessons	Every lesson
Explain the reasoning behind an idea	2	41	50	8
Represent and analyse relationships using tables, charts or graphs	5	85	10	0
Work on problems for which there is no immediately obvious method of solution	35	61	4	0
Use computers to solve exercises or problems	89	11	0	0
Write explanations about what was observed and why it happened	1	43	52	4
Put events in order and give a reason for the organisation	20	70	9	1

Reactions to incorrect responses

In this next group of questions, shown in Table 5.4, teachers were asked to identify the frequency with which they responded in a number of different manners to students' incorrect responses. Only the responses from the secondary mathematics teachers are included in the table, as the responses from the science teachers and the primary teachers were very similar to these.

The questioning techniques of the teachers at both primary and secondary levels can be inferred from this table. In most lessons, when a student provided an incorrect answer, the teacher either continued asking other students for their answers and then discussed with the class what the correct answer might be, or they asked the student another question to try and prompt for the correct answer. It was uncommon for teachers to say that they simply correct students' answers in front of the class on a regular basis. Instead, if they did as they reported, they provided students with other opportunities to answer correctly.

Table 5.4 Percentage Responses to 'In your mathematics lessons, how frequently do you do the following when a student gives an incorrect response during a class discussion?'

	Never or almost never	Some lessons	Most lessons	Every lesson
Correct the student's answer in front of the class	35	53	10	3
Ask the student another question to help him or her get the correct response	2	27	56	16
Call on another student who's likely to give the correct response	13	68	17	2
Ask other students to give their responses and then discuss what is correct	3	41	46	11

Students' work arrangements

The items shown in Figure 5.20 explore the students' working arrangements in the classroom, that is whether the classroom is generally teacher focused or more likely to be student focused. The questions in the TIMSS teacher questionnaire were posed for primary teachers with reference to their mathematics classes.

The first two items look at whether students worked predominantly individually, with or without assistance from the teacher. The second two items look at whether and how the students worked as a whole class, and the third pair of items examines the extent and way that the classes worked in small groups.

What these response data indicate is that in all three areas: primary; secondary mathematics; and secondary science, there was no one overwhelmingly preferred method of teaching. The teachers used a variety of classroom techniques and methods of responding to the class and to individual students. In secondary mathematics the students were somewhat more likely than the primary students to work individually, both with and without the assistance of the teacher. Mathematics students at both levels were more likely to work individually in most or every lesson than the science students. In science, where practical work is more often undertaken, the students were just as likely to be working individually, in small groups or as a whole class.

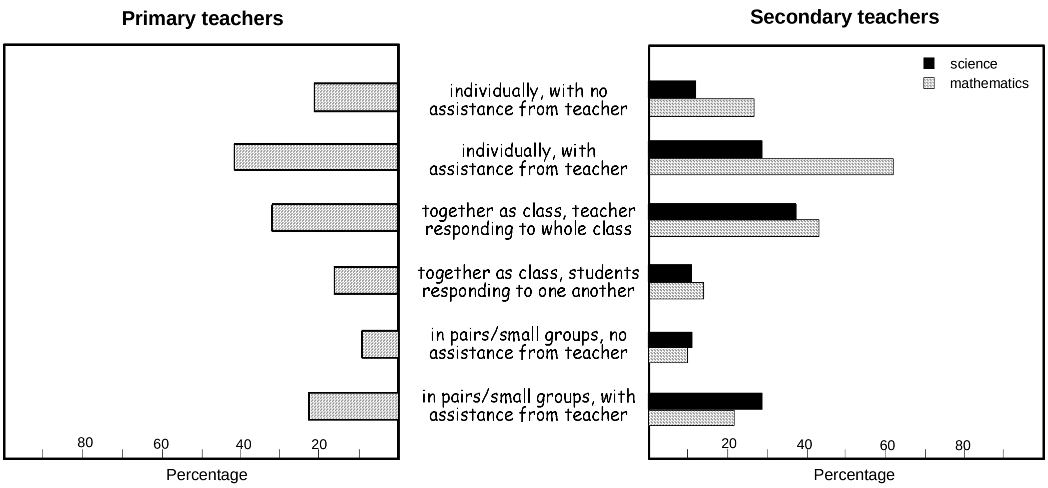


Figure 5.20 Percentages of Teacher Groups Reporting Use of Student Work Patterns 'Most Lessons' or 'Every Lesson'

The least used strategy at primary level was having students work in pairs or small groups without assistance from the teacher – but only 15 per cent of the teachers said they never or almost never had their students work in this way. At secondary level, about a third of the mathematics teachers never or almost never had their students working together as a class with students responding to one another; working in pairs or small groups without assistance from the teacher; or working individually without assistance from the teacher. These three strategies were also least used by the science teachers, but only a fifth said that they never or almost never had their students working in these ways.

Construction of the teacher-level factors

The next step in the construction of the multilevel model of student achievement was to examine teacher variables suggested by the literature review to be important for student achievement. In particular, this section of the report examines whether the individual teacher items that have been explored earlier in this chapter can be formed into meaningful constructs.

In order to do this, exploratory principal components factor analysis was carried out.[i] The results of these analyses will be reported separately for Population 1 teachers with regards to mathematics and for Population 2 mathematics and science teachers. Similar analysis was not carried out in science for Population 1 as the questionnaire focussed on teachers' beliefs about mathematics. The items used in the principal components analysis were those that were explored in the early part of this chapter. The results of the principal components analyses are shown in Appendix 3, together with their reliabilities,[ii] and are summarised in the following sections of the report.

Primary teachers

The most interpretable solution for the primary teachers was found to be the one consisting of six factors. The items comprising each factor are also shown and briefly summarised below.

Factor 1 appears to reflect a problem-solving approach to classroom organisation and teaching. The items that grouped onto this factor were:

I: Problem-solving approach to teaching

- In mathematics lessons students often work in pairs or small groups with assistance from the teacher;
- In mathematics lessons students often work in pairs or small groups without assistance from the teacher;
- Students are frequently asked to work on problems for which there is no obvious method of solution;
- Students are frequently asked to explain the reasoning behind an idea;
- Students are frequently asked to represent relationships using tables, charts or graphs;
- In mathematics lessons students often work together as a class with students responding to one another; and
- Students are frequently asked to use computers to solve exercises or problems.

The second factor can be thought of as describing teachers who have a more traditional approach to teaching mathematics. The items that grouped onto this factor were:

II: Traditional approach to teaching

- In mathematics lessons students often work together as a class with the teacher teaching the whole class;
- Students are frequently asked to practice computational skills;
- In mathematics lessons students often work individually with assistance from the teacher;
- When a student gives an incorrect answer, other students are asked to give their responses and then there is discussion about which is correct; and
- When a student gives an incorrect answer, the student is asked another question to help him or her get the correct answer.

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i Principal components analysis is a method of statistical analysis designed to reduce the complexity of data by identifying variables tending to cluster together in groups or components, distinct from other clusters. The principal components analysis produces 'loadings' that represent the association between each item and each component. Loadings of greater than 0.3 or less than -0.3 are conventionally used to indicate which variables are associated with a particular component. For the principal components analyses reported here, this convention was followed.

ii Reliability is a statistical measure indicating how well the items in the derived factors are consistently measuring the same variable.

Teachers scoring highly on the third factor believed that for students to be good at mathematics they need to have a deeper understanding of it. The items loading onto this factor were:

III: Importance of student understanding

- To be good at mathematics in school it is important that students be able to provide reasons to support their solutions;
- To be good at mathematics in school it is important that students understand how mathematics is used in the real world;
- To be good at mathematics in school it is important that students be able to think creatively; and
- When a student gives an incorrect answer, the student is not simply corrected in front of the class.

Factor four reflects a view of mathematics as a structured, formal way of representing real world relationships. The items representing this factor were:

IV: Mathematics as structured, real-world representation

- Mathematics is primarily a practical and structured guide for addressing real situations;
- To be good at mathematics in school it is important that students think in a sequential and procedural manner;
- Mathematics is primarily a formal way of representing the real world;
- To be good at mathematics in school it is important that students understand mathematical concepts, principles and strategies; and
- More than one representation should be used in teaching a mathematics topic.

The focus of factor five is on procedural beliefs. High scores on this factor reflect a view that mathematics is an abstract subject, and one best learnt as a set of algorithms or rules. The items that loaded onto this factor were:

V: Mathematics as sets of rules and procedures

- Mathematics should be learned as sets of algorithms or rules that cover all possibilities;
- Basic computational skills on the part of the teacher are sufficient for teaching primary school mathematics;
- If students are having difficulty, an effective approach is to give them more practice by themselves during the class;
- To be good at mathematics in school it is important that students remember formulas and procedures; and
- Mathematics is primarily an abstract subject.

Factor six reflects teachers' self-perceptions of their own worth as a teacher. Teachers scoring high on this subscale felt that their students and society as a whole appreciated their work, and would be less likely to change to another career if given the opportunity. The items that grouped onto this factor were:

VI: Teaching as a profession

- Your students appreciate your work;
- Society appreciates your work; and
- You would not change to another career if you had the opportunity.

Secondary school teachers

The same procedure of principal components analysis was then carried out with the items answered by both the secondary school mathematics and science teachers. For both groups of teachers, the five-factor solution provided the most readily interpreted set of results. The results of these principal components analyses are shown in Appendix 3 for mathematics and science teachers, along with suggested underlying constructs. The results of each of the principal components analyses are summarised separately in the following sections of this report.

Mathematics teachers

The factors derived from this analysis for the secondary mathematics teachers are quite similar to those found for the primary teachers. Items that characterise teaching using a problem-solving approach again clustered together to reflect this underlying construct. Teachers who scored high on this factor asked students to work on problems for which there are no immediate solutions, had the students work in groups, and used a variety of representations for particular topics. The items that loaded onto this factor were:

I: Problem-solving approach to teaching

- In mathematics lessons students often work in pairs or small groups without assistance from the teacher;
- In mathematics lessons students often work in pairs or small groups with assistance from the teacher;
- Some students have a natural talent for maths, some don't;
- Students are often asked to use computers to solve problems;
- In mathematics lessons students often work together as a class with students responding to each other;
- In mathematics lessons students are often asked to represent and analyse relationships using tables, chart, graphs; and
- In mathematics lessons students are often asked to work on problems for which there is no immediate or obvious method solution.

Teachers who scored highly on the second factor were likely to be those whose classrooms reflected traditional teaching practices. These teachers were more likely to have students working individually in their classes, and to believe that students need a knowledge of rules and procedures to do well at mathematics. The items that loaded onto this factor were:

II: Traditional approach to teaching

- To be good at maths it's important for students to remember formulas and procedures;
- In mathematics lessons students often work individually with assistance from the teacher;
- In mathematics lessons students often work individually without assistance from the teacher;
- Students are frequently asked to practice computational skills;
- Students having difficulty need more practice in class;
- When a student gives an incorrect answer they are usually corrected in front of the class; and
- When a student gives an incorrect answer it is usual to call on another student who's likely to give the right response.

The third factor reflects teachers' beliefs about the level of deeper understanding required of their students. Teachers scoring high on this factor believed that mathematics is grounded in the real world and that it should be used as a tool for representing the real world. The items that loaded onto this factor were:

III: Mathematics as real-world representation; importance of student understanding

- To be good at mathematics it is important for students to understand how mathematics is used in the real world;
- Mathematics is primarily a practical guide for addressing real problems;
- To be good at mathematics it is important for students to be able to provide reasons for their solutions;
- To be good at mathematics it is important for students to be able to think creatively;
- To be good at mathematics it is important for students to be able to understand mathematical concepts and ideas; and
- Mathematics is primarily a formal way of representing the world.

Factor four is similar to that already described for primary teachers. This factor mainly describes the classroom environment, and reflects beliefs about methods of teaching mathematics and ways of responding to incorrect answers from students. The factor includes the following items:

IV: Mathematics as sets of rules and procedures

- Mathematics should be learned as sets of rules or algorithms that cover all possibilities;
- Students are frequently asked to explain the reasoning behind an idea;
- When a student gives an incorrect answer, they are usually asked another question to help them to get the right response;
- When a student gives an incorrect answer, other students are asked to give their response and then there is discussion about which is correct;
- More than one representation should be used when presenting a mathematics topic;
- Basic computational skills are all that are needed for teaching primary school mathematics;
- In mathematics classes students often work together as a class with the teacher teaching the whole class; and
- A liking for and understanding of students are essential for teaching mathematics.

Factor five, as with primary teachers, reflects teachers' perception of whether they were appreciated by their students and society, as well as how satisfied they were in their jobs. The items that loaded onto this factor for the secondary mathematics teachers were:

V: Teaching as a profession

- Your students appreciate your work;
- Society appreciates your work;
- You would not change to another career if you had the opportunity; and
- Teaching was your first choice as a career when beginning your training.

Science teachers

The first of the factors again broadly reflects a problem-solving approach to classroom organisation and teaching. The items loading on this factor represent teachers' beliefs about methods of teaching science, including classroom structure. The items were:

I: Problem-solving approach to teaching

- Students are often asked to work on problems for which there is no obvious method of solution;
- Students are often asked work together as a class with students responding to one another;
- Students are often asked to explain the reasoning behind an idea;
- When a student gives an incorrect answer the student is often asked another question to help him or her get the correct answer;
- Students are often asked to write explanations about what was observed and what happened;
- Students are often asked to put events of objects in order and give a reason for the organisation;
- Students are often asked to work in pairs or small groups with assistance from the teacher;
- Students are often asked to represent and analyse relationships using tables, charts or graphs; and
- When a student gives an incorrect answer other students are asked to give their responses and then there is discussion about which is correct.

The second factor reflects a view of science as a tool for addressing real world problems. Teachers scoring high on this factor also commonly reported having their students work autonomously. The items that loaded onto this factor were:

II: Science as a tool for practical problems

- Science is primarily a formal way of representing the real world;
- Science is primarily a practical and structured guide for addressing real situations;
- Science is primarily an abstract subject;
- Students are often asked to use computers to solve exercises or problems;
- Students often work in pairs or small groups without assistance from the teacher; and
- Students often work individually without assistance from the teacher.

The third factor grouped together items that reflect a belief in students needing to understand the uses of science and think reflectively about what they do. The items that loaded on it were:

III: Importance of student understanding

- To be good in science it is important for students to be able to provide reasons to support their solutions;
- To be good in science, it is important for students to understand scientific concepts, principles and strategies;
- To be good in science it is important for students to understand how science is used in the real world; and
- To be good in science it is important for students to be able to think creatively.

Factor four reflects mainly a traditional approach to teaching science, with a focus on formulas and detailed procedures for experiments, and on teaching to the whole class as a group. The items that loaded onto this factor were:

IV: Traditional approach to teaching

- To be good in science it is important for students to remember formulas and procedures;
- To be good in science it is important for students to think in a sequential & procedural manner;
- It is important for teachers to give students prescriptive and sequential directions for doing science experiments;
- When a student gives an incorrect answer, their error is usually corrected in front of the class;
- Some students have a natural talent for science and some do not;
- When a student gives an incorrect answer it is usual to call on another student who is likely to give the right response;
- Focusing on rules is a bad idea. It gives students the impression that the sciences are a set of procedures to be memorised; and
- Students often work together as a class with the teacher teaching the whole class.

Factor five, as with primary teachers and secondary mathematics teachers, reflects teachers' satisfaction with their job. The items that loaded onto this factor were:

V: Teaching as a profession

- Society appreciates your work;
- Your students appreciate your work; and
- You would not change to another career if you had the opportunity.

Summary

This chapter has explored the teacher-level data available from the TIMSS study. In the first part of the chapter, the background of the teachers involved was examined. In general, the teachers were found to be an ageing population, with most teachers in the 30- to 50-year age group. It was shown that there are more female teachers entering the profession than male teachers, and it was found that most of the primary teachers and approximately half of the mathematics and science teachers participating in TIMSS were female. Approximately a quarter of the secondary teachers held post-graduate qualifications plus teaching qualifications, and there was a trend for the male teachers to have a higher level of qualification than the female teachers. Student achievement levels were shown to be positively related to level of teacher qualification, but this reached somewhat of a plateau at degree qualification level.

Teaching was the first choice of profession for the majority of the TIMSS teachers, particularly the primary teachers (of whom most were female) and more so for secondary mathematics teachers than science teachers. About half of the mathematics and science teachers surveyed said they would change profession if they could, but fewer than half of the primary teachers made this claim. Teaching was more often a first choice of career for the females than the males, and a wish to change career was found to be more commonly expressed by the males than the females.

The male teachers had a stronger view that society appreciated their work, and, except for mathematics teachers (among whom female teachers held the stronger view), that students also appreciated their work.

Few major differences were found between primary and secondary teachers in beliefs about what is important for students to be good at mathematics. The main difference was in the belief that students should understand how mathematics is used in the real world, with primary teachers expressing stronger views about its importance. No comparison was made between secondary science teachers' and primary teachers' views on these items as the focus of the primary teachers' questionnaire was on the mathematics classroom. However the main finding for science teachers was their high level of belief (held by 84 per cent of the respondents) in the importance of students' being able to provide reasons to support their solutions.

Mathematics was seen by the majority of teachers as a formal way of representing the world and as a practical and structured guide for addressing real situations, rather than as an abstract subject. Similar findings were obtained for science. Strong levels of agreement were found for the notion that some students have a natural talent for mathematics and for science while other students do not.

The next section examined beliefs about teaching mathematics. On the strategy of students having difficulty being given more practice in class, teachers were fairly evenly split. This was the only item on which such differences were found. Most teachers agreed that more than one representation should be used when teaching a particular topic, and that a liking of students was essential for teaching mathematics. Most teachers disagreed with mathematics being learned as sets of global algorithms or rules, and with basic computational skills being sufficient for teaching primary school mathematics. Interestingly, more primary than secondary teachers agreed with the latter statement, although the number was not high.

Teachers were asked how often they asked students to perform a range of different tasks in the classroom. Similar responses were made by secondary mathematics and science teachers (the questions were not asked of primary school teachers). What was most notable about the responses to these items was that relatively little use was made of computers in either the mathematics or science classrooms (but it must be remembered that the data were collected in 1994), and that methods of teaching using problem solving were also infrequently used.

Responses to the items asking about teachers' strategies on receipt of incorrect answers from students were similar for all three groups of teachers. The main response was reported to be asking the student another question to prompt for the correct answer or to continue asking the class and then discuss what the correct answer is. Teachers were also asked about students' work arrangements in mathematics and science classes. What could be inferred from their responses was that teachers generally use a variety of styles in the classroom, with no one style predominating.

Finally, a series of principal components analyses looked at the items examined in this chapter and attempted to build a manageable number of meaningful teacher-level constructs to use in a multilevel analysis. For primary teachers the most interpretable solution was found to be that with six factors. These factors could best be described as representing:

- I: a problem-solving approach to teaching;
- II: a traditional approach to teaching;
- III: a teaching approach emphasising thinking and understanding;
- IV: a view of mathematics as a structured, formal way of representing real world relationships;
- V: a view of mathematics as an abstract subject best learnt as sets of rules and procedures; and
- VI: attitude to teaching as a profession.

For each of secondary mathematics and science teachers, five-factor solutions were found to be the most interpretable. While different items loaded onto the factors in some cases, similar factors were defined for mathematics teachers to those found for primary teachers, with the exception of the fifth factor.

For science teachers the factors could be described as:

- I: a problem-solving approach to teaching;
- II: a view of science as a tool for addressing real-world problems;
- III: a teaching approach emphasising thinking and understanding;
- IV: a traditional approach to teaching; and
- V: attitude to teaching as a profession.

In the next chapter the school-level data are examined in a similar fashion.

Notes

[1] S. Lerman, The role of the teacher in children's learning of mathematics. In A. J. Bishop, K. Hart, S. Lerman & T. Nunes (eds), Significant Influences on Children's Learning in Mathematics. UNESCO, Paris, 1993 (p. 62).

[2] M. O. Martin & D. L. Kelly (eds), *Technical Report Volume I: Design and Development*. Boston College, Chestnut Hill, Massachusetts, 1996, p. 5-2.

Chapter 6

Analysis of the School Data

The first part of this chapter contains a description of some of the characteristics of the Australian primary and secondary schools participating in TIMSS at the Population 1 (mid primary) and Population 2 (lower secondary) levels. The information is provided for context-setting purposes, and includes such variables as locality of school, size of school and class size.

The second part of the chapter examines a number of school factors that may influence student achievement. One of these could be labelled as school climate, as measured by the frequency that school administrators say they have to deal with problems such as levels of absenteeism, attendance levels in class and at school, classroom disturbances, vandalism and levels of physical and verbal abuse of students. Other factors examined include the economic, social and health backgrounds of the students enrolled at the school and the extent to which shortage of resources is thought by principals to hamper instruction, both generally and specifically in mathematics and science. Finally, the extent and type of provision of remedial and enrichment programs in mathematics and science is examined, along with the level of streaming in mathematics and science in both primary and secondary schools.

State and territory representation

Participating schools were selected at random from a list of all schools, with a greater chance of larger schools being selected than smaller schools. The sampling was representative of the student population distribution in Australia as a whole. In Australia, 179 schools at Population 1 and 180 schools at Population 2 participated in TIMSS, coming from all states and territories, and from the three education sectors. The distribution by state and territory of participating primary and secondary schools, together with the number of schools by sector, is shown in Table 6.1.

Table 6.1 Distribution of TIMSS Schools by State/Territory and Sector

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Population 1									
Government	24	18	23	20	16	16	9	7	133
Catholic	3	5	7	4	5	3	2	3	32
Independent	3	1	2	3	1	1	1	2	14
Total	30	24	32	27	22	20	12	12	179
Population 2									
Government	23	20	20	17	19	16	6	4	125
Catholic	6	9	5	5	4	1	2	2	34
Independent	3	4	5	3	3	2	0	1	21
Total	32	33	30	25	26	19	8	7	180

Locality of schools

Table 6.2 shows that most schools were located within urban communities, as would be expected from the distribution of Australia's population. Up to 50 per cent of the Australian Population 1 and 2 students came from the inner and middle metropolitan areas. There were slightly more Population 2 schools located in outer metropolitan areas and country towns. The percentage of schools with fewer than 1000 people in the community was slightly higher for Population 1 schools, at 7 per cent, than for Population 2 schools (4 per cent).

Table 6.2 Locality of TIMSS Schools

	Percentage of schools	
Location	**Pop. 1**	**Pop. 2**
A small isolated community	3	1
A small rural centre (fewer than 1 000 people)	4	3
A country town (1 000 to 9 999)	13	14
A country or provincial town (10 000 or more)	16	18
A semi-rural/outer metropolitan area/suburb	14	19
An inner suburban area (within about 5 km of city centre)	13	18
A suburban area, neither outer nor inner	37	28

School size

Total enrolment in the Population 1 and 2 schools ranged from 39 to 1967 and 106 to 1597 students, respectively. Over half the schools participating at Population 1 had fewer than 500 students enrolled as compared to 20 per cent of the schools participating at Population 2.

Table 6.3 Student Enrolments of TIMSS Schools

	Percentage of schools	
	Pop. 1	**Pop. 2**
Fewer than 250 students	32	4
Between 250 and 500 students	38	18
Between 501 and 750 students	23	26
Between 751 and 1000 students	6	30
Between 1001 and 1250 students	1	16
Over 1250 students	1	5

School composition

Eleven per cent of schools at the Population 2 level and a smaller number of schools at the Population 1 level, usually independent schools, catered for both full primary and full secondary schooling. A large majority of schools at Population 1 catered for full primary and at Population 2 catered for full secondary schooling.

Table 6.4 Year Levels catered for by TIMSS Schools

	Percentage of schools	
Year level range	**Pop. 1**	**Pop. 2**
Full primary and full secondary	3	11
Full secondary	-	71
Full primary	86	-
Lower to mid-secondary	-	13
Other combinations	11	5

Class sizes

Schools were asked to provide information about average class sizes for both the upper and lower grades at each population level. Table 6.5 shows a summary of these class sizes. For all grade levels at both primary and secondary school, it appears that the average class size was about 26, though this varied somewhat from state to state. In general, primary classes were both larger and smaller than secondary classes, and a greater percentage of primary schools had class sizes of 30 or more students. In one primary school there were 52 students across two grades, taught with a team teaching approach.

Table 6.5 Class Sizes for TIMSS Schools

	Lower grade	**Upper grade**
Population 1		
Range	3 – 52*	2 – 35
Mean	26	25
Mode	30	30
% of classes with ≥ 30 students	26.2	28.4
Population 2		
Range	7 – 33	13 – 33
Mean	26	26
Mode	25	25
% of classes with ≥ 30 students	22.5	23.1

* The class with 52 students contained two grades taught with a team teaching approach.

School climate

Principals were asked a number of questions pertaining to the behaviour of their students. The following sections report how frequently school administrations reported dealing with particular problems that might influence the learning environment in a school. Some principals did not respond to these questions. The percentages illustrated pertain to the 155 Population 1 and 140 Population 2 schools for which the information was provided.

Lateness to school

Figure 6.1 shows the frequency with which school administrations reported needing to deal with the problems of student lateness to school. While student lateness to school was clearly a much greater problem for secondary schools than for primary schools, it generally involved only a small percentage of students. For most primary schools it was reported as a problem with only up to one per cent of students, while for most secondary schools the figure was up to two per cent. The picture was bleaker in about 18 per cent of primary schools and about 30 per cent of secondary schools, where lateness was reported as a problem with five per cent or more of the students.

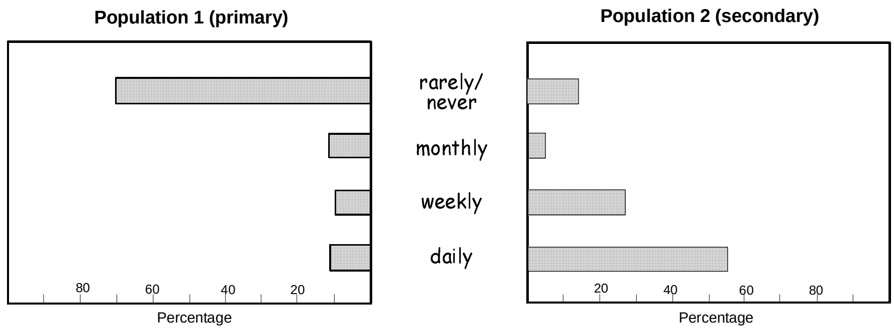

Figure 6.1 Frequency with which School Administration Reported Dealing with Student Lateness to School

Absenteeism

Student absenteeism is described in the TIMSS questionnaire as being unjustified absence from school. As is clearly shown in Figure 6.2, absenteeism was a much greater problem for the secondary schools than for the primary schools surveyed, although again most commonly associated with only two per cent or fewer of the students at each level.

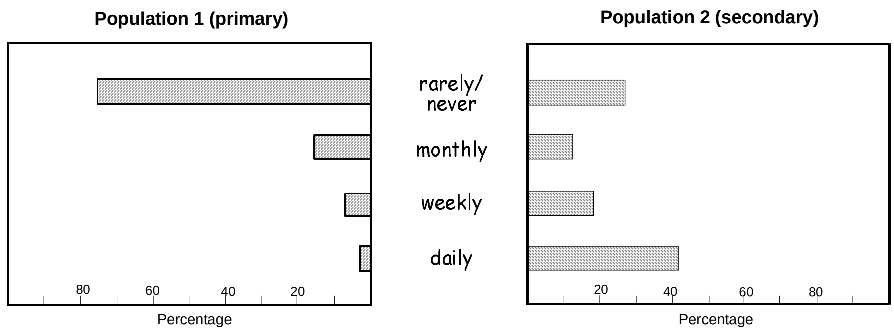

Figure 6.2 Frequency with which School Administration Reported Dealing with Student Absenteeism

Skipping classes

Figure 6.3 shows the frequency with which the TIMSS primary and secondary school administrations said they dealt with students skipping classes. As would be expected, this occurred very rarely with primary school students. With secondary school students, however, it was far more prevalent, with 20 per cent of schools reporting that it was a problem they dealt with on a weekly basis and 27 per cent on a daily basis.

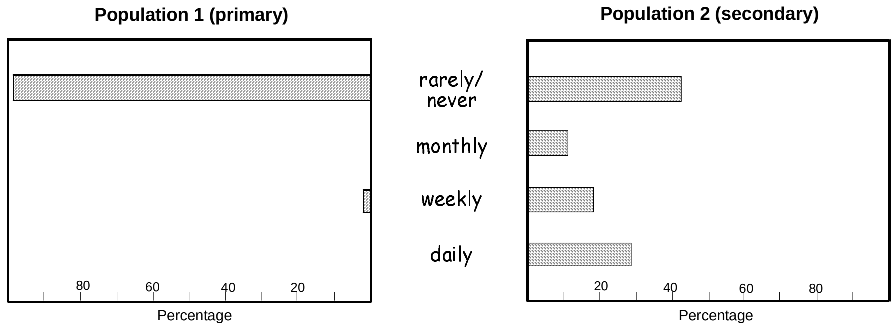

Figure 6.3 Frequency with which School Administration Reported Dealing with Students Skipping Classes

As with the behavioural problems already discussed, only small percentages of students (two per cent or fewer) were reported to be involved in skipping classes, although some 15 per cent of primary and secondary schools reported this as a problem with five per cent of students or more.

Classroom disturbance

Dealing with classroom disturbances appears to be a much more common problem for school administrators. While 30 per cent of primary schools and 10 per cent of secondary schools reported that they rarely or never had to deal with classroom disturbances, for almost 17 per cent of primary schools and half of the secondary schools this was a daily occurrence. The profiles of reported frequencies for the TIMSS schools are shown in Figure 6.4.

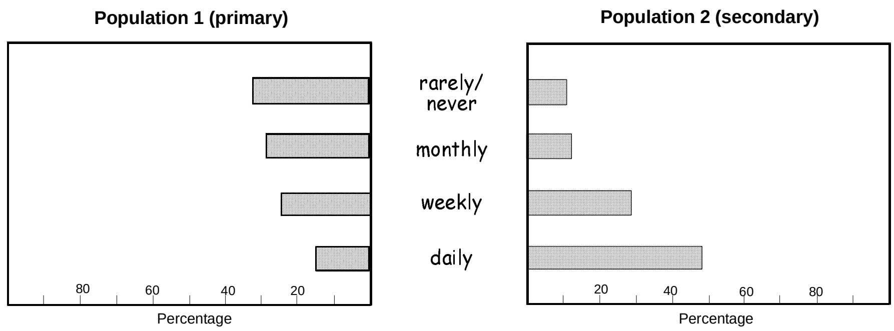

Figure 6.4 Frequency with which School Administration Reported Dealing with Classroom Disturbances

Vandalism

At the time of TIMSS, vandalism appeared not to be a major problem in primary schools, but was again more common in secondary schools. Almost 13 per cent of primary schools and 17 per cent of secondary schools reported vandalism problems involving five per cent or more of their students. The frequencies reported by principals (or other administrative staff) of the TIMSS schools are illustrated in Figure 6.5. Very similar statistics about needing to deal with theft were also reported. In more than four-fifths of the schools, fewer than two per cent of the students were involved in either vandalism or theft.

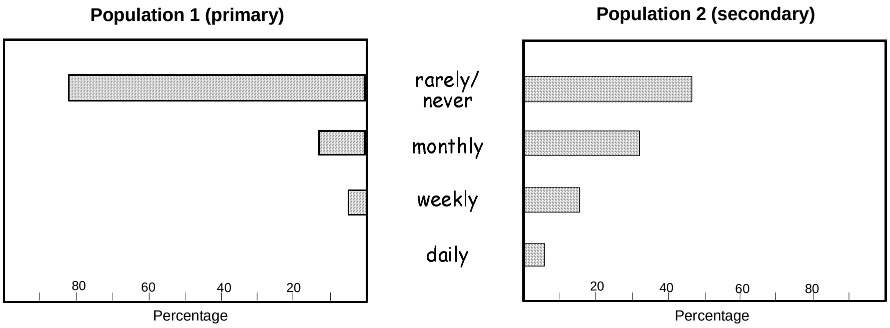

Figure 6.5 Frequency with which School Administration Reported Dealing with Vandalism

Intimidation or verbal abuse of students

For students to be able to perform well in school, they must feel that it is a safe place for them. The next three items examined administrators' perceptions of the environment of their schools.

The first of these items deals with intimidation or verbal abuse of students, for which the data are shown in Figure 6.6. Unfortunately, it was not uncommon for both primary and secondary school principals to report spending time on a weekly or even a daily basis dealing with this problem.

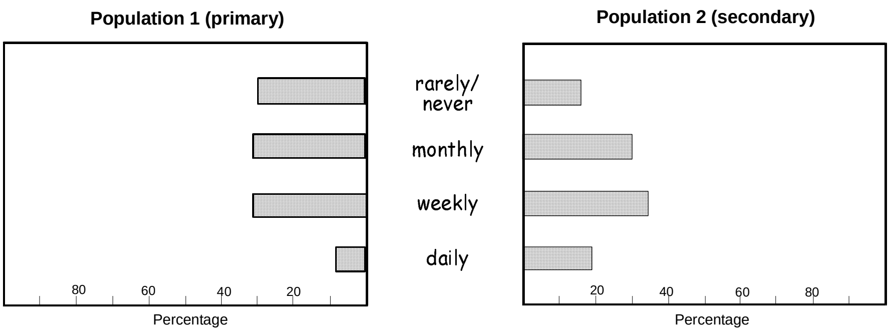

Figure 6.6 Frequency with which School Administration Reported Dealing with Intimidation or Verbal Abuse of Other Students

For secondary schools in particular, 35 per cent of the TIMSS principals reported spending time dealing with this problem on a weekly basis while almost 19 per cent reported dealing with it on a daily basis. A third of the principals reported that it involved more than five per cent of their students. Of further concern was that almost 40 per cent of primary school administrators reported spending time dealing with this problem on a weekly or daily basis, and that half of these principals reported that the problem involved more than five per cent of their students.

Physical injury to other students

Just over half of the primary and secondary school principals reported that they rarely or never had to deal with physical injury to their students. However Figure 6.7 shows that it was a weekly or daily problem for almost 19 per cent of primary schools and 17 per cent of secondary schools.

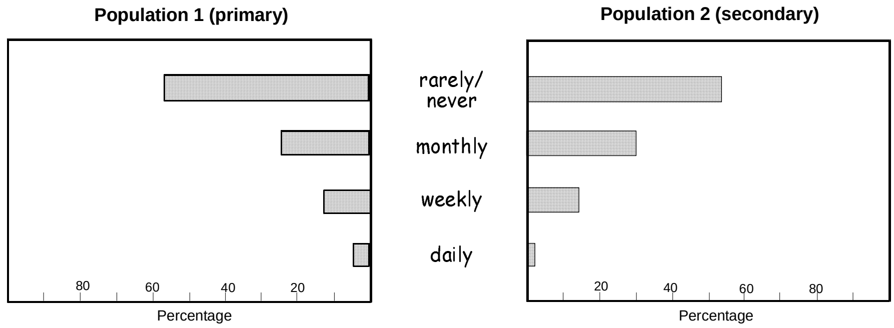

Figure 6.7 Frequency with which School Administration Reported Dealing with Physical Injury to Students

It is not apparent why this figure was similar for the primary schools and the secondary schools, unless the question was interpreted as accidental injury as opposed to deliberate injury.

Intimidation of teachers

Intimidation of teachers is more likely to be a problem at the secondary school level, and this was borne out in the TIMSS data presented in Figure 6.8. For approximately 85 per cent of the primary schools and 54 per cent of the secondary schools it was a rare occurrence, but for almost five per cent of primary schools and 16 per cent of secondary schools it was a problem dealt with on a weekly or daily basis.

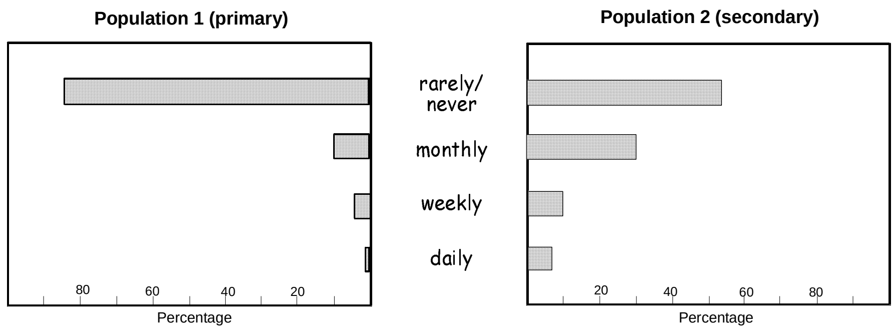

Figure 6.8 Frequency with which School Administration Reported Dealing with Intimidation of Teachers

As would be expected, the percentage of students involved in such intimidation was lower for primary schools than for secondary schools.

Economic, social and health problems of students

The well-being of the student body in a school is often regarded as a very important factor in the educational environment experienced by the teachers and students. As indicators of student well-being, principals were asked to provide the approximate percentages of students in their schools with particular economic, social and health problems from a range listed. The most common of these were found to be students from disadvantaged backgrounds who qualified for a government-funded education assistance allowance (23 per cent of both primary and secondary students), and students from one-parent families (20 per cent of primary and 22 per cent of secondary students).

More students were reported to have learning problems (14 per cent of both primary and secondary students) than either health (7 per cent of primary and secondary students) or nutrition problems (6 per cent of primary and 5 per cent of secondary students). On average, only five per cent of primary and six per cent of secondary students came from homes in which neither parent received more than a primary education, and 12 per cent of primary students and 10 per cent of secondary students had a first language different to that used for teaching in the school.

For each of the ‘problems’ identified in the questionnaire there were schools reported as having no student in the school with that particular problem. Eighteen per cent of primary schools and five per cent of secondary schools reported no student from a disadvantaged background, while 21 per cent of primary and 15 per cent of secondary schools reported having no student speaking a first language other than that used for instruction. Only one primary school and six secondary schools reported having no student with learning difficulties. Nine per cent of primary and 12 per cent of secondary schools reported no student with any health problems, and about a third at each level reported no student with nutrition problems.

How principals spend their time

Principals were asked to indicate the amount of time spent on a range of listed activities. On average, principals from both Populations 1 and 2 indicated that most of their time was spent on internal administrative tasks, including regulations, school budget and timetabling issues. The next greatest amount of time was spent communicating with parents, counselling and disciplining students and responding to requests from state or regional educational officials. Primary principals spent more time teaching than secondary principals. Secondary principals spent substantially more time on representing the school at official meetings or in the community.

Cooperation and collaboration among teachers

Principals were asked to what extent cooperation and collaboration among teachers in their schools was a matter of policy and practice. Just under half of both primary and secondary TIMSS schools had an official policy in place to promote cooperation and collaboration among teachers. However, in almost all schools, principals reported that teachers were encouraged to share and discuss instructional ideas and materials, and met regularly to discuss these issues.

Shortages considered to affect instruction

Principals were asked to consider to what extent their school’s capacity to provide both general instruction and instruction specifically in mathematics and science was affected by a shortage or inadequacy of a number of listed resources. Table 6.6 shows that two thirds or more of the TIMSS principals at both Population 1 and Population 2 levels had little or no concern about shortages of instructional materials, budget for supplies, or about the school physical environment generally. The latter included the school buildings and grounds, heating/cooling and lighting systems and instructional space. Over half of the principals at each level had little or no concern about the provision of special equipment for students with special needs.

Table 6.6 Extent to which the School's Capacity to Provide General Instruction is Hampered by Shortages of Resources

	Population 1 (%)				Population 2 (%)			
	none	*a little*	*some*	*a lot*	*none*	*a little*	*some*	*a lot*
Instructional materials	41	37	19	3	47	33	18	2
Budget for supplies	49	30	15	5	57	20	16	7
School buildings and grounds	34	33	24	9	28	38	23	10
Heating/cooling and lighting systems	57	24	15	5	49	29	20	2
Instructional space	44	22	23	11	39	33	20	9
Special equipment for students with special needs	26	31	33	11	15	41	29	15

Table 6.7 provides information about principals' perceptions of the effect of shortages of particular resources on the delivery of mathematics and science instruction. For both mathematics and science, over two-thirds of principals reported that they had little or no concern about shortages of calculators, library materials or audio-visual resources. However about half of the principals reported that the schools' capacity to provide mathematics and science instruction was hampered to a moderate extent by shortages of both computer hardware and software. (To put this in perspective, the data were collected in 1994.) The poor provision of laboratory equipment for science was deemed to be a problem for science instruction for 58 percent of primary schools and 29 percent of secondary schools.

Table 6.7 Extent to which the School's Capacity to Provide Mathematics and Science Instruction is Hampered by Shortages of Resources

	Population 1 (%)				Population 2 (%)			
	none	*a little*	*some*	*a lot*	*none*	*a little*	*some*	*a lot*
Mathematics instruction								
Computers	22	31	30	16	19	30	35	16
Computer software	17	29	30	24	17	33	32	19
Calculators	54	33	12	2	61	30	8	1
Library materials	27	45	26	3	33	44	19	4
Audio-visual resources	24	44	27	6	26	47	22	6
Science instruction								
Laboratory equipment	8	34	37	21	28	43	23	6
Computers	18	30	30	22	13	34	33	20
Computer software	12	26	32	30	8	39	30	23
Calculators	47	37	10	6	62	24	11	3
Library materials	24	43	26	6	32	39	24	6
Audio-visual resources	21	43	27	10	28	38	29	6

Provision of remedial and enrichment programs

As shown in Table 6.8, about half the schools at both levels reported that they offered both remedial and enrichment programs in mathematics. About a third of the secondary schools reported offering some form of remedial science program, while this was true for only a very few primary schools. About a quarter of the primary schools and approaching half of the secondary schools replied that they offered some form of science enrichment program. The percentages shown in the table were computed on the assumption that 'no response' to these questions meant that the school had no programs. The actual percentages could well be higher than those shown in the table, as these questions were answered by only 55 to 60 per cent of the principals.

Table 6.8 Provision of Remedial and Enrichment Programs in Mathematics and Science

	Population 1	Population 2
	*% yes**	*% yes***
Remedial teaching – mathematics	47	51
Remedial teaching - science	5	32
Special enrichment programs – mathematics	44	48
Special enrichment programs – science	26	40

* Assuming non-responses (N = 59) meant that the schools had no program
** Assuming non-responses (N=67 to 75) meant that the schools had no program

Principals were asked to indicate by using four categories how these enrichment and remedial activities were organised. The four categories provided were:

- Groups formed within regular mathematics/science classes;
- Students withdrawn from their regular mathematics/science class;
- Students receiving extra tuition before or after school; or
- Other.

These categories are not of course discrete; schools may employ a variety of strategies in dealing with students who need remediation or enrichment. Table 6.9 provides a summary of the answers to these questions from the approximately 60 per cent of principals who responded.

For both primary and secondary schools it was most common for remediation and enrichment programs to be carried out within the regular classroom, with students forming a separate group within the class. Withdrawal of students from their regular classes for mathematics enrichment was more common for primary school than secondary school students, and for secondary science students, enrichment was more likely to take the form of extra tuition.

Table 6.9 Manner in which Remedial or Enrichment Programs were organised

	Percentage of schools			
	Students form a group in regular classes	*Students are withdrawn from their regular classes*	*Students receive extra tuition*	*Other*
Population 1				
Remedial mathematics	87	62	19	16
Remedial science	82	9	25	9
Enrichment mathematics	86	41	16	25
Enrichment science	59	26	28	44
Population 2				
Remedial mathematics	67	63	37	28
Remedial science	62	38	40	24
Enrichment mathematics	67	24	46	43
Enrichment science	53	14	57	42

Available courses in mathematics and science (streaming)

Ninety per cent of primary schools reported that they did not stream students in their upper grade level in mathematics, and 97 per cent did not stream in science. Of the few schools that did stream for mathematics, the decision on which group students should belong to was based primarily on academic performance and teacher recommendations, and to a lesser extent on entrance examinations. There were too few schools reporting streaming in science to be able to draw any conclusions from the data.

The classes of 58 per cent of the Australian Population 2 student respondents were streamed for mathematics instruction at the upper grade level. Fewer than 20 percent of schools streamed for science at the upper grade level. Analysis of the data grouped according to whether the student came from a class that was classified as ‘streamed’ (no matter what the level of the stream), compared with those who came from schools where streaming was not used, showed that the ‘streamed’ students as a total group performed significantly better than the ‘unstreamed’ students in both mathematics and science. To some extent these differences would have been due to grade, however, as streaming was more common in the upper than in the lower grade.

Streaming in both mathematics and science at the secondary school level was reported to be carried out primarily on the basis of academic performance, supported by teacher recommendations, and rarely on the basis of entrance examinations. In mathematics, streaming was more commonly practised in non-government than government schools and was much more common in some states than others.

Correlations with achievement

The rationale for including the school climate and school level student variables examined in this chapter was that they could have a bearing on student achievement. The school climate variables on which data were collected are all characteristics of a negative rather than a positive environment. In Table 6.10 the pairwise correlations of these variables with the aggregated student science and mathematics achievement scores are shown.[i] The results

i Aggregated scores are school-wide average scores for each of mathematics and science achievement.

indicate, especially for secondary schools, which reported a much higher rate of occurrence of these behaviours, that higher levels of the particular behaviour were moderately strongly associated with lower levels of achievement in both mathematics and science.

Table 6.10 Significant Correlations* of School Climate Variables with Mathematics and Science Achievement

	Population 1		Population 2	
Behaviour**	**Mathematics achievement**	**Science achievement**	**Mathematics achievement**	**Science achievement**
Lateness to school			- 0.31	-0.29
Absenteeism	- 0.21	- 0.27	-0.36	-0.31
Skipping classes			-0.36	-0.33
Classroom disturbance	- 0.19	- 0.21	-0.31	-0.21
Vandalism			-0.22	-0.18
Intimidation of students	- 0.21	- 0.24	-0.35	-0.29
Physical injury to students	- 0.20	- 0.23	-0.18	
Intimidation of teachers			-0.38	-0.32

* Correlations not shown unless significant at $p < .05$ or better; correlations less than 0.20 significant at $p < .05$, all others significant at $p < .01$

** Frequency of occurrence, as reported by principals

Table 6.11 provides correlations between the school-level student background characteristics (*what percentage of your students…*) and achievement, and shows moderate to strong negative correlations on almost all of these variables. Again, the variables on which data were collected were all characteristics associated with a negative rather than a positive learning environment. From the correlations shown, it could be concluded, for example, that schools with high proportions of students from a disadvantaged background, or with high proportions of students whose parents have low levels of education, are likely to achieve at lower levels in mathematics and science.

Table 6.11 Correlations* of School-level Student Background Variables with Mathematics and Science Achievement

	Population 1		Population 2	
Background variable**	**Mathematics achievement**	**Science achievement**	**Mathematics achievement**	**Science achievement**
Disadvantaged background	- 0.45	- 0.47	-0.60	-0.61
Parents with primary education only	n/a	n/a	-0.42	-0.50
One-parent families	- 0.29	- 0.29	-0.24	-0.18
Language other than English	- 0.20	- 0.26	-0.26	-0.40
Learning problems	- 0.26	- 0.28	-0.34	-0.30
Health problems	- 0.24	- 0.23	-0.30	-0.30
Nutrition problems	- 0.25	- 0.27	-0.54	-0.56

* Correlations less than 0.20 significant at $p < .05$, all others significant at $p < .01$

** Percentage of the school’s enrolment, as reported by principals

Summary

There is a variety of school factors that may influence student learning, some directly and some indirectly. The school climate variables on which data were collected in TIMSS provide an overview of the incidence of behaviours in the school that are regarded as detrimental to the development of a safe learning environment. In most cases only a small proportion of students were responsible for such behaviours, although some schools have to deal with such behaviours on a weekly or daily basis.

Another factor which is believed to be of relevance to students' achievement at school is the provision of resources. In TIMSS these were investigated both generally, in the form of instructional materials, supplies, buildings and grounds, and specifically for mathematics and science in the form of computer hardware and software, library and audio-visual resources, and laboratory equipment. Most principals believed that instruction in their school was not hampered to any great extent by lack of general resources, but lack of some subject-specific resources was seen to hamper instruction to a considerable extent: computer hardware and software, particularly for science but to a lesser extent for mathematics; and science laboratory equipment for primary schools. (Circumstances may well have changed since that time, given that the data were collected in late 1994.)

Remedial and enrichment programs were found to be more commonly provided in mathematics than in science. Many schools reported offering some form of remediation or enrichment in mathematics, and the programs were offered in different ways – including forming a group within the class (the most common method reported), withdrawal of students, and provision of extra tuition.

Most primary schools reported that they did not stream their students for either mathematics or science, and streaming for secondary science was uncommon. Where streaming in science occurred it tended to be state-based, suggesting that this may have been a matter of policy. However, almost three-fifths of the schools reported streaming in mathematics, and selection of students into streamed classes was primarily carried out on the basis of academic achievement and teachers' recommendations.

When the school climate and school-level student background characteristics were examined separately in relation to achievement, several were found to be significantly correlated with either mathematics or science achievement, or both. Such variables always interact in complex ways, and a better picture can be obtained by considering them simultaneously as clusters of variables. In the next chapter, student achievement in mathematics and science is examined through more complex statistical techniques. In these analyses, effects on achievement of student-, teacher- and school-level variables are hypothesised, and models are built to examine the joint effects.

Chapter 7

School and Classroom Variations in Mathematics and Science Achievement

Introduction

One of the methods for investigating influences on achievement outcomes is to study systematically the variation in these outcomes among schools, classrooms and students. TIMSS provides data that enable the association of student, classroom, and school-level factors with student achievement in mathematics and science to be investigated. In this chapter these correlates of achievement in mathematics and science in primary school and junior secondary school in Australia are investigated. The investigation makes use of two broad approaches. The first approach uses multilevel statistical analysis of variation in achievement in relation to measures of school and classroom characteristics. The second approach compares schools and classrooms where students performed significantly better than would have been predicted with corresponding characteristics of schools and classrooms where performance was not as good as would have been predicted.

Multilevel statistical analysis of mathematics achievement

Literature from two or three decades ago suggested that schools had little direct effect on student achievement and placed its emphasis on the social backgrounds of students and their contexts. Over a period of about 25 years there have been important developments that have provided new insights into the effects of schooling and greater confidence that these effects can be beneficial. Two of these developments have been the adoption of new methods for analysing data that are crucial in studies of school effects and the emergence of a view that school and classroom effects need to be studied in terms of changes in achievement over time.

The application of statistical methods that take account of the hierarchical nature of most data has facilitated a better understanding of school, student and classroom influences on achievement[1]. There is now recognition that teacher, classroom and school variables may contribute to achievement to at least the same extent as social background and context[2]. Other studies that have made use of these methods have shown that contextual variables such as student body composition and organisational policies play an important role in mathematics achievement.

The second major development has been recognition of the importance of using data that measure achievement in relation to prior ability. Ideally studies have measured achievement in an area at more than one point in time and have focused on achievement growth rather than static achievement at a particular time. It has become widely accepted that the use of growth measures has enabled the better identification of school and classroom influences. The approach has become represented in terms such as intake-adjusted or value-added measures of outcomes. Willet[3] observes that only by measuring change is it possible to 'document each person's progress and, consequently, to evaluate the effectiveness of education systems'. A meta-analysis of school effects (adjusted for prior achievement) concluded that school effects accounted for approximately 8 to 10 per cent of the variation in student achievement, and that school effects were greater for mathematics than for language[4].

Although TIMSS data are cross sectional rather than longitudinal, they include a measure of verbal ability (a Word Knowledge test). It is possible to use this measure to make allowance for prior achievement. Even though it is not equivalent to having longitudinal data on achievement in mathematics and science it provides a control for differences in general ability.

Data for the TIMSS study were collected at three levels- student-level, classroom-level and school-level, and so multilevel modelling techniques were used to develop a model that adequately reflects the structure of the data. When examining mathematics achievement, a three-level model could be developed, as Australia, unlike most other countries in TIMSS, collected data for two classes per school. In this way we are able to examine, at both Grade 4 and Grade 8, differences between schools, differences between classes within schools, and differences between students. When examining science achievement however, a two-level model was specified, collapsing class and school-level data into a single level. This had to be done as students were generally split amongst more than two science classes, meaning that class sizes were a great deal smaller than those for mathematics classes, and in general too small for multilevel analysis.

The aim of this analysis of the TIMSS data was to attempt to identify the factors at the student, classroom and school levels for both the primary and secondary school populations that influence student achievement in mathematics.

Measures and variables

Outcome measures

The outcome measures were the results of the TIMSS tests in mathematics and science at Population 1 (primary school) and Population 2 (secondary school). Due to the nature of the age of transfer to secondary school in the different states of Australia, a common year level was taken for both the primary and secondary school data. Grade 4 was chosen for population 1 and Grade 8 for Population 2, and the analyses reported in this chapter utilise only these data. Because each student completed one of several test booklets with linked items, Item Response Theory (IRT) methods were used to analyse the achievement data and create a mathematics and a science score for each student (see Chapter 3). This means that regardless of which booklet a student answered there are common accurate measures of their mathematics and science achievement.

Independent variables

Table 7.1 provides details of the variables that were used in the analysis. In that table the variables are organised in groups as student level, classroom level and school level variables. While some of these variables were not found to be significant influences on achievement in the univariate and multivariate analyses, those analyses did not take into account the inherent multilevel structure of the data, hence they are all included in the multilevel analysis for completeness.

Student background variables

Level 1 variables are those most directly related to the students themselves. In addition to student gender, a number of other background variables were incorporated in the analysis. Socioeconomic status (SES) was computed as a weighted composite comprising the higher of mother's or father's occupational status, the higher of mother's and father's level of education (secondary students only), and possessions in the home[5]. Ethnicity was measured as a weighted composite variable based on student's birthplace, the birthplaces of their parents and the primary language spoken at home. The number of books in the home was used as an indication of the cultural background of the student. In addition the number of people living in the student's household was included.

Table 7.1 Student, Classroom and School Variables[i]

STUDENT LEVEL	
Student background variables	
Sex	Student's gender
Books	Number of books in student's home
Family size	Number of people living in student's home
Ethnicity	A composite of student's birthplace, birthplace of parents and language spoken at home
SES	A composite variable representing family wealth
Student mediating variables	
Word knowledge	Verbal ability as measured by the Word Knowledge test
Attitude to mathematics	Student's attitude towards mathematics.
Importance of maths	Perceived importance of mathematics to the student (Pop. 2 only)
CLASSROOM LEVEL	
Classroom composition variables	
Class mathematics attitude	Average score on "attitude for mathematics" for the class
Class word knowledge score	Average score on word knowledge test for the class
Classroom teacher variables	
Age	Teacher's age
Gender	Teacher's gender
Education qualifications	Teacher's qualifications
Years teaching	Number of years teaching
Factor 1	Problem-solving approach to teaching
Factor 2	Discipline oriented approach to teaching
Factor 3	Process oriented approach to teaching
Factor 4	Eclectic approach to teaching
Factor 5	Teacher satisfaction with job
Factor 6	Algorithmic approach to teaching (Pop. 1 only)
SCHOOL LEVEL	
School size	Measure of the number of students in the school
Maths time	Time allocated to mathematics teaching during a week
School location	Location of the school; with rural and remote schools compared to urban schools
Mean SES	Average SES for the school

Student mediating variables

Students completed a Word Knowledge test as a measure of their prior verbal ability[6]. The test was used in both the First and Second International Science Studies, and the importance of language skills has been shown to be important for achievement in mathematics. Both attitude to mathematics and the students' belief in the importance of mathematics were considered to be important factors in mathematics achievement, and so were included as variables at this level of the analysis.

Classroom variables

Level 2 variables include those variables that are related to the characteristics of the classroom. These can include both characteristics of the class itself and characteristics of the teacher and their teaching style. Mean Word Knowledge score was derived at the class level, to provide a variable that would account for students in classes that were streamed for ability in some manner. A mean score was derived for attitudes to mathematics as well, to test whether this affected the performance of students in classes with high or low levels of positive attitude towards mathematics.

i Measured at both Population 1 and Population 2 unless otherwise stated

Teacher background attributes — gender, age, number of years teaching and educational qualifications — were also included. Scales representing teacher attitudes and beliefs about mathematics and teaching were developed. These scales are described in greater detail in Chapter 5, and are summarised in Table 7.1. Six subscales were derived for primary teachers and five for secondary teachers.

School level variables

At the final level of the analysis, a number of characteristics that related to the characteristics of the school were examined. Mean socioeconomic status scores were derived for each school to provide a control for the social composition of the school. For secondary schools only, a measure of the school size was used, ranging from schools of less than 250 students through to schools of more than 1250 students. Also included in the analysis was the school's location in terms of whether it was classed as an urban, rural or remote school, and the time spent in a week teaching mathematics or science.

Analysis

Hierarchical linear modelling (using MlwiN[7]) was used to look at the interrelationships between factors at the student, classroom and school levels. This procedure allows modelling of outcomes at several levels (e.g. student level, classroom level, school level), partitioning separately the variance and effects at each level while controlling for the variance across levels. To examine the effects of different variables on mathematics achievement, a model was built by successively adding blocks of variables.

For instance, in examining effects on achievement in mathematics, the first model included the group of student background variables comprising gender, socioeconomic status, family size, ethnicity and number of books in the home. The second model added a set of mediating variables to the set of student background factors. The mediating variables included results on a standardised Word Knowledge test, and attitudes towards mathematics. The third model contained the classroom composition variables of mean word-knowledge score and the class mean for attitudes to mathematics. These variables were included to take into account variations in the average ability of a class that could be attributed to policies such as streaming. It is assumed that a high-streamed class would have higher levels of both verbal ability and more positive attitudes to mathematics than a low-streamed class.

The next model added the set of teacher variables including the teacher gender, age, qualifications, years of teaching and scores on the scales related to teachers' attitudes and practices in mathematics teaching. The final model added the school-level variables, which included school size (for secondary schools) and location as well as the mean school socioeconomic level. The models are shown progressively in Figure 7.2 for primary students and Table 7.3 for secondary students. The parameter estimate is shown along with its standard error in brackets. In general estimates must be twice the size of their standard error in order to be statistically significant, and those that are significant are shown bolded.

This comprehensive range of variables is included to gauge the relative significance of the variables in contributing to explanation of variance in the outcome measure. In the primary school sample, 70 per cent of the explained variance in mathematics achievement was associated with differences among students within classrooms, 12 per cent was associated with differences between classrooms, and 18 per cent with differences between schools. In the secondary school sample the corresponding percentages were 57 per cent, 32 per cent and 11 per cent. In other words there were greater differences between schools at primary than secondary level, and greater differences between classes at secondary level, but at both levels most of the variation was among individual students (and that was explained more by verbal ability than by other factors).

Table 7.2 Estimates of Influences on Mathematics Achievement in Schools, Population 1, TIMSS

	Model 1	Model 2	Model 3	Model 4
	student background characteristics	Model 1 with student mediating variables	Model 2 with teacher and classroom characteristics	Model 3 with school characteristics
Intercept	**510.0 (7.0)**	**523.8 (6.3)**	**516.5 (14.6)**	**524.9 (20.1)**
Student-level variables				
Background variables				
Female	-3.4 (2.1)	**-6.2 (1.9)**	**-12.2 (2.3)**	**-15.4 (3.1)**
Books in the home	**9.7 (1.0)**	**3.1 (1.0)**	**5.4 (1.2)**	**3.9 (1.7)**
SES	**17.6 (1.2)**	**11.2 (1.1)**	**8.1 (1.3)**	**7.2 (1.9)**
Ethnicity	1.2 (0.5)	0.7 (0.4)	-0.3 (0.5)	-0.3 (0.7)
Family Size	**-5.3 (0.8)**	**-1.6 (0.7)**	-0.3 (0.9)	0.4 (1.2)
Mediating variables				
Word knowledge		**40.2 (1.1)**	**37.2 (1.4)**	**38.9 (1.9)**
Positive attitudes towards maths		**17.5 (1.1)**	**18.8 (1.2)**	**19.5 (1.7)**
Classroom-level variables				
Classroom composition				
Mean word-knowledge			**16.8 (2.5)**	**14.6 (4.8)**
Mean attitude to maths			-0.8 (2.2)	2.2 (3.5)
Teacher attributes				
Age			-4.6 (3.5)	-6.1 (4.6)
Gender			-7.5 (5.0)	0.2 (7.2)
Educational qualifications			2.3 (1.5)	2.8 (2.1)
Teaching experience			0.6 (0.4)	0.4 (0.6)
Teaching practices				
Problem-solving approach			1.7 (2.4)	2.5 (3.3)
Discipline oriented approach			-4.3 (2.5)	-1.1 (3.4)
Process oriented approach			3.7 (2.8)	0.6 (4.2)
Eclectic approach			-3.8 (2.7)	-3.5 (3.7)
Algorithmic approach			-1.3 (2.3)	-1.0 (3.7)
Teacher satisfaction with job			0.8 (2.5)	-1.9 (3.6)
School-level variables				
Mean SES				4.6 (5.1)
Amount of time on maths				-0.8 (3.5)
Remote				-21.5 (27.6)
Rural				-0.8 (8.5)

Results

Primary school students

Number of books in the home, socioeconomic status, family size and ethnicity were all found to be statistically significant when the first block of variables was added. Socioeconomic status and books in the home, a measure of the cultural resources of the family, were both found to be significant positive predictors of mathematics achievement. Family size, however, was found to be a significant negative predictor, indicating that students from larger families tended to have lower levels of achievement in mathematics.

The mediating variables (Word Knowledge and Attitude to mathematics) have strong independent effects at this level of schooling. They are influential predictors of engagement. Indeed the effect of verbal ability is by far the largest of any variable in this model (this is after controlling for the effects of socioeconomic status and other background variables). This means that when the effects of other variables are examined, they are net of the effects of verbal ability. Possibly the most important finding at this point is that girls' achievement levels are significantly lower than those of boys at the primary school level, after "taking out" the effects of verbal ability.

It is of some consequence that *Positive attitudes to mathematics* has an influence on mathematics achievement after controlling for verbal ability and student background. This means that it is not just that more able students hold more positive attitudes to mathematics but also that attitudes have an independent influence on achievement.

The mediating variables not only have strong independent effects, they also transmit or relay the effects of the student background variables. This is evident from the marked drop in sizes of the estimates for socioeconomic status, books in the home, ethnicity, and family size when the mediating variables are added to the model.

As well as student-level factors, classes and schools also influence student achievement. For primary school students, the mean ability level of the class, as measured by the average Word Knowledge score, was found to be a significant factor in mathematics achievement. The addition of further blocks of variables measuring other aspects of the classroom – teacher attributes and teacher beliefs about mathematics and mathematics teaching – had little impact. The school-level variables: mean socioeconomic status of the school, amount of time spent on teaching mathematics, and locality of the school were also not significant, however the addition of these other explanatory variables removed the significance of the effect of family size.

Secondary students

Number of books in the home and socioeconomic status were both found to be strong positive predictors of achievement in the secondary school sample. Students from family backgrounds rich in resources both in terms of possessions in the form of books, performed at significantly higher levels than those students whose family backgrounds were poorer in either or both. Males and those students from smaller families performed at significantly higher levels than females and those from large families respectively, although these differences were not as great as for the socioeconomic variables.

As with the primary school students, the mediating variables (verbal ability and positive attitude to maths) were found to have strong independent effects. While the effect of verbal ability was not quite as strong as with the primary school sample ($t = 36.5$ for primary schools, $t = 31.2$ for the secondary sample), the effect of positive attitudes to mathematics was found to be stronger ($t = 15.9$ for the primary school sample, $t = 23.6$ for the secondary school sample). This effect is independent of verbal ability, and indicates both that more able students hold more positive attitudes to mathematics and that attitudes also have a strong positive independent effect on achievement. These mediating variables not only have independent effects, they also transmit the effects of other variables. The effect of gender, for example, appears to be relayed through verbal ability, as the significant gender effect (albeit small) disappears after the addition of the verbal ability variable. In other words, mathematics achievement would be similar for male students and female students with similar verbal ability skills.

The final column of Table 7.3 provides us with estimates of the effects on student achievement with all predictor variables included. At the classroom level, the average class levels of verbal ability and attitudes to mathematics are positive predictors of achievement. Students in classes with stronger overall levels of verbal ability and with strong positive attitudes to mathematics will achieve at higher levels than those students in classes with low levels of verbal ability or with poor attitudes to mathematics. Higher levels of average verbal ability in a classroom imply that some form of streaming is occurring, and this finding suggests that streaming has an effect on students' mathematics scores over and above the student's own mathematical ability. Average school socioeconomic status also has a moderately strong positive effect on achievement. These results show that the higher the mean socioeconomic composition of the school, the higher the achievement level. These findings suggest that there are benefits for students to be in classes and schools where they rub shoulders with other higher socioeconomic status and higher ability students.

None of the teacher variables that were investigated, and none of the school variables other than average socioeconomic status, were found to have any influence on student achievement. This is not to say that teachers and schools don't have an influence: we know that they do from the amount of variance at each level. This simply means that the measures included in this TIMSS analysis, or indeed those measured by the TIMSS survey instruments, were not those that have a particularly strong effect on mathematics achievement.

Table 7.3 Estimates of Influences on Mathematics Achievement in Schools, Population 2, TIMSS

	Model 1	Model 2	Model 3	Model 4
	student background characteristics	Model 1 with student mediating variables	Model 2 with teacher and classroom characteristics	Model 3 with school characteristics
Intercept	**491.3 (7.2)**	**500.0 (6.4)**	**492.1 (12.3)**	**496.9 (14.7)**
Student-level variables				
Background variables				
Female	**-4.4 (2.0)**	-2.8 (1.8)	-2.5 (2.0)	-2.5 (2.0)
Books in the home	**9.8 (0.9)**	**7.0 (0.8)**	**6.9 (0.9)**	**6.8 (0.9)**
SES	**16.2 (1.1)**	**12.4 (1.0)**	**11.4 (1.1)**	**10.2 (1.1)**
Ethnicity	-0.3 (0.8)	-0.4 (0.8)	-0.8 (0.8)	-0.7 (0.8)
Family Size	**-1.9 (0.7)**	-1.0 (0.6)	-0.6 (0.7)	-0.5 (0.7)
Mediating variables				
Word knowledge		**28.2 (0.9)**	**26.8 (1.0)**	**27.0 (1.0)**
Positive attitudes towards maths		**18.9 (0.8)**	**18.9 (0.9)**	**19.0 (0.9)**
Classroom-level variables				
Classroom composition				
Mean word-knowledge			**26.5 (2.1)**	**18.2 (2.4)**
Mean attitude to maths			3.6 (2.1)	**5.5 (2.0)**
Teacher attributes				
Age			1.8 (3.2)	1.8 (3.2)
Gender			-5.7 (3.9)	-5.7 (3.9)
Educational qualifications			0.5 (1.2)	0.5 (1.2)
Teaching experience			0.0 (0.4)	0.0 (0.4)
Teaching practices				
Problem-solving approach to teaching			-3.5(2.0)	-3.5 (2.0)
Discipline oriented approach to teaching			-1.5 (2.0)	-1.5 (2.0)
Process oriented approach to teaching			-3.2 (1.9)	-3.2 (1.9)
Eclectic approach to teaching			-2.4 (2.0)	-2.4 (2.0)
Teacher satisfaction with job			0.8 (2.0)	0.8 (2.0)
School-level variables				
Mean SES				**12.6 (2.2)**
School size				0.5 (1.8)
Amount of time on maths				-3.0 (1.9)
Remote				-7.6 (13.9)
Rural				7.0 (4.4)

Discussion

In terms of percentages of variance in achievement explained, results from these multilevel analyses show, consistent with current research on school effectiveness, that not only do schools make a difference, but classrooms as well. There are strong classroom effects and modest school effects in secondary schools and moderate classroom and school effects in primary schools.

For both primary and secondary schools, the pooling of student resources that is associated with the grouping of students — reflected by average verbal ability at both primary and secondary school level and mean SES as well at secondary level — heavily influence mathematics achievement. Achievement is highest in those classes and schools with higher concentrations of students from middle class families and students with higher verbal ability.

State level differences

As there were found to be state variations in achievement in both mathematics and science[8], a four-level multilevel analysis was also carried out with state as the fourth level. This analysis showed quite clearly that although there were state differences, differences within states were far greater than those between states (see Figure 7.1). As a result, separate multilevel analyses were carried out for each of the five major mainland states. These were carried out as two-level analyses, as there was only data from one class for most of the schools, and so this analysis examines school or class - level differences and student-level differences. Table 7.4 shows the parameter estimates for those variables that were significant in each state, as well as the proportion of variance that was found to be explainable at each of the two levels, and the proportion of this variance accounted for by the multilevel model specified.

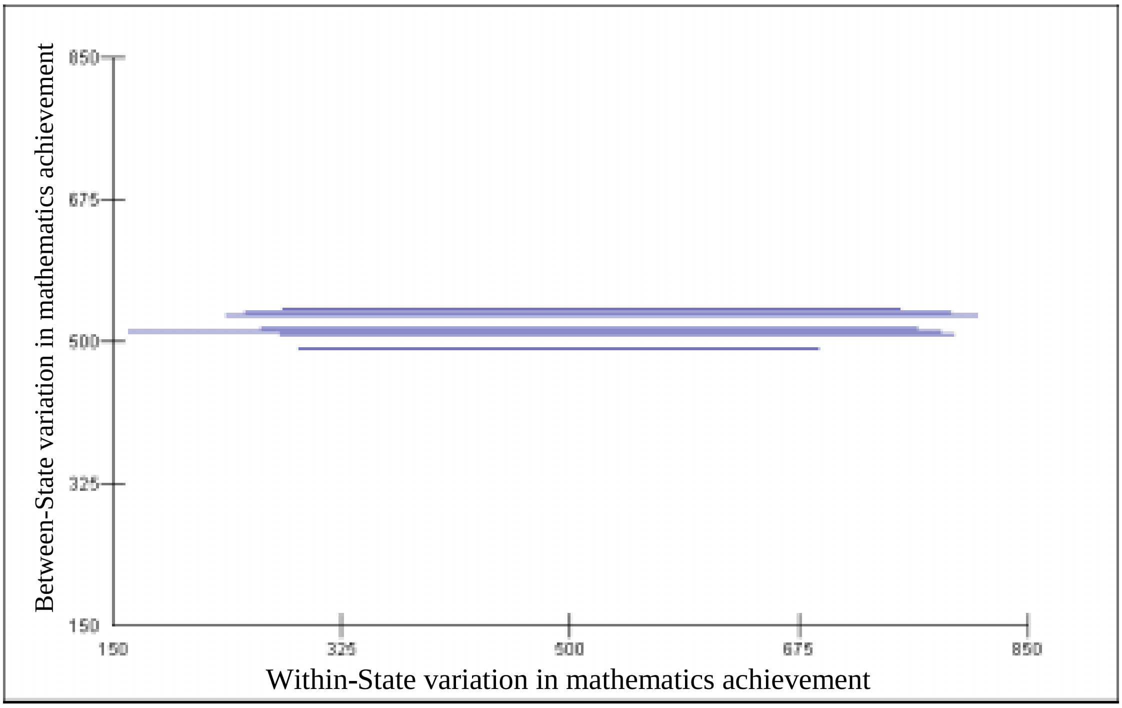

Figure 7.1 Between-State vs Within-State Variation on Mathematics Achievement

Table 7.4 Significant Estimates of Influences on Mathematics Achievement in Schools, by State, Population 1, TIMSS

	NSW	VIC	QLD	SA	WA
Proportion of variance (%)					
School / class-level	38	17	26	44	24
Student-level	62	83	74	56	76
Student-level variables					
Background variables					
Female	-10.7 (3.8)				-22.1 (5.2)
Books in the home					7.6 (2.6)
SES	12.5 (2.1)	15.8 (2.9)		10.6 (3.0)	9.2 (3.0)
Ethnicity					
Family Size					
Mediating variables					
Word knowledge	38.7 (2.2)	39.9 (2.8)	47.9 (3.5)	40.1 (3.4)	35.7 (2.7)
Positive attitudes to maths	19.5 (1.9)	18.1 (2.8)	17.2 (2.9)	20.3 (3.1)	16.7 (2.8)
Classroom-level variables					
Teacher attributes					
Age			14.9 (4.6)		
Gender			31.7 (10.2)		
Educational qualifications			8.5 (2.5)		
Teaching experience					
Classroom composition					
Mean word-knowledge	25.6 (3.9)	11.8 (4.8)	17.8 (4.7)	17.7 (5.2)	18.5 (4.9)
Teacher approaches					
Problem-solving approach			23.1 (5.6)		
Discipline oriented approach			11.9 (5.2)		
Process oriented approach					
Eclectic approach					
Algorithmic approach					
Teacher satisfaction with job					
School characteristics					
Mean SES					
School size					
Amount of time on maths			13.4 (4.6)		
Remote					
Rural					
Proportion of variance explained by model (%)					
School / class level	81	72	93	64	76
Student level	38	37	35	31	37

As was expected, given that between-state differences were overshadowed by within-state differences, results for the five larger states are reasonably similar. There are also, however, some notable differences. These could be summarised as follows:

- Significant gender differences were found in two states (New South Wales and Western Australia) after allowances were made for socioeconomic factors and prior verbal ability. In both states males achieved at significantly higher levels than females.
- Number of books in the home was a significant predictor only in Western Australia.

- Teacher effects were only found to be a significant influence in Queensland, with mathematics achievement significantly higher for those students with older teachers, male teachers, and those teachers with higher education qualifications. In addition, achievement was higher in Queensland for students whose teachers used a problem solving approach or a discipline oriented approach to teaching.
- Amount of curriculum time allocated to mathematics was found to be a significant influence on student achievement only in Queensland.

Socioeconomic status was found to be a significant influence on achievement in all states except for Queensland.

Individual-level word knowledge and positive attitude to mathematics, and classroom-level word knowledge, were found to be the strongest predictors in every state. At this level (Grade 4), it is perhaps not surprising that the effect of verbal ability on mathematics achievement is so strong, but this finding has very important implications for policy regarding early numeracy. It would appear to be vital for young children to develop strong literacy skills if they are to achieve high numeracy skills. This may reflect a growing trend towards teaching mathematics skills in context, contexts that frequently require good verbal ability skills. In addition, the grouping of students (either intentionally or incidentally) into classes with other highly literate and numerate students would appear to amplify the individual-level effects of prior verbal ability.

Other than in Queensland, socioeconomic status has a moderate effect on achievement. In each of the other states it is those students who have well-educated parents, in professional jobs, and with a high level of family wealth, who achieve well in mathematics.

The findings for the Population 2 sample were more generally stable across states, as shown in Table 7.5. In New South Wales, females performed at a significantly lower level than males, after accounting for all other factors. In all states except for New South Wales, number of books in the home was found to be a significant influence on achievement.

Consistently across all states, individual word knowledge score and positive attitudes to mathematics were found to be largest significant predictors of mathematics achievement, although not of the same magnitude as for the primary school sample. Books in the home (except in NSW) and socioeconomic status were consistently found to be moderately significant predictors of achievement.

Discussion

What can be learned from this examination of state differences? Firstly, that the differences in achievement reported in TIMSS monograph 1[9] are difficult to explain with the data contained in the TIMSS student, teacher and school questionnaires. More light may be shed on details by the analysis of data from the TIMSS R-Video study.

Secondly, that the differences between states, after taking into account factors such as prior verbal ability and socioeconomic status, are not as great as the differences within states. This is what one would realistically expect given the homogeneity of the population between states.

Thirdly, that there are particular factors that appear to affect student achievement in mathematics across all states. These are prior verbal ability (word knowledge), positive attitudes to mathematics, and at Grade 8 level, socioeconomic status and sociocultural background.

Table 7.5 Significant Estimates of Influences on Mathematics Achievement in Schools, by State, Population 2, TIMSS

	NSW	VIC	QLD	SA	WA
Proportion of variance (%)					
School / class-level	55	25	29	36	42
Student-level	45	75	71	64	58
Student-level variables					
Background variables					
Female	-8.6 (3.5)				
Books in the home		11.8 (2.0)	4.3 (2.0)	10.0 (2.3)	4.5 (2.0)
SES	8.4 (1.9)	14.3 (2.3)	10.9 (2.5)	10.4 (2.6)	12.8 (2.4)
Ethnicity					
Family Size					
Mediating variables					
Word knowledge	23.7 (2.0)	24.5 (2.2)	32.9 (2.2)	26.5 (2.2)	23.6 (2.2)
Positive attitudes to maths	10.3 (1.7)	22.2 (8.7)	24.3 (2.0)	21.7 (2.2)	19.6 (2.1)
Classroom-level variables					
Teacher attributes					
Age					
Gender					
Educational qualifications					
Teaching experience					
Classroom composition					
Mean word-knowledge	46.6 (4.0)	12.6 (4.7)			28.8 (3.9)
Teacher approaches					
Problem-solving approach					
Discipline oriented approach					
Process oriented approach					
Eclectic approach					
Algorithmic approach					
Teacher satisfaction with job					
School characteristics					
Mean SES		8.7 (3.5)	13.6 (3.5)	18.2 (3.9)	
School size					
Amount of time on maths					
Remote					
Rural					
Proportion of variance explained by model (%)					
Student level	85	84	82	79	84
School / class level	40	33	28	28	21

Multilevel statistical analysis of science achievement

Hierarchical linear modelling was also used to examine the influence of school and student level influences on science achievement. For the analysis of science achievement at Population 2 some schools were excluded because students were located in classrooms with small numbers of students. This arose because the sample was based on mathematics classes and in some schools those students were distributed across a number of different science classrooms. Due to the resulting reduced sample size at each level, the model was restricted to two levels, the first being student-level and the second classroom/school-level.

As was the case for the analysis of mathematics achievement, the first model included the group of student background variables comprising sex, socioeconomic status, family size, ethnicity and number of books in the home. The second model added a set of mediating variables to the set of student background factors. The mediating variables included results on a standardised word-knowledge test, attitudes towards science, and for the secondary school students, perceived importance of science. The final model added the set of classroom or school composition variables relating to mean word-knowledge score, mean attitude to science, mean socioeconomic status, location of the school (rural or remote), and time allocated for science.

Results from analyses of science achievement are shown in Table 7.6 (primary students) and Table 7.7 (secondary students). The discussion that follows is based primarily on the final model, which is shown in the fourth column of each table. For both the Population 1 sample and the Population 2 sample, 79 per cent of the explained variance in science achievement was associated with differences among students within schools and 21 per cent was associated with differences between schools.

In terms of student background variables it can be seen that all of the student background variables contribute to differences in science achievement at both Population 1 and Population 2 level. The influences of all of these variables are greater at Population 2 level than at Population 1 level, indicating a widening equity gap in terms of gender, ethnicity, socioeconomic and sociocultural background between primary and secondary school.

Other things equal, there is more of a gender gap (in favour of males) in the early secondary school years than there is at primary school level, and similarly there is a greater difference according to socioeconomic background at secondary than primary school. The higher the level of socioeconomic status, the more likely students are to be able to access resources such as well-educated parents who also have the financial resources to obtain extra help if it is required. Books in the home is a stronger influence at the secondary level than at the primary level, as is family size. Ethnicity has the weakest effect on achievement at both population levels, however these data suggest that there is a cultural bias in the presentation of science at both school levels.

The mediating variables (Word Knowledge and Attitudes towards science) have independent effects on science achievement at both Population 1 and Population 2 levels. As well, the effect represented by word knowledge is greater at the Population 2 level than was observed in the analysis of mathematics achievement. Achievement in secondary school science appears to be more strongly linked to verbal ability than achievement in mathematics. As was found in the analyses of mathematics achievement motivational factors (i.e. positive attitudes to science) also impact on achievement in science, even after allowance is made for other influences.

The social composition of classes (as measured by mean SES) has a weak positive effect on achievement at the secondary school level, but not at primary school. Average word knowledge has a weak effect at primary school but a strong effect at secondary school, indicating that verbal (and perhaps reading) ability is of greater importance at the secondary level when science becomes less teacher-driven and requires more individual work.

The school-level variables time allocated to science in the curriculum, and location of the school in a rural or remote area, had no significant effect on achievement in science.

Table 7.6 Estimates of Science Achievement: Schools, Classrooms and Students, Population 1, TIMSS

	Model 1	Model 2	Model 3
	student background characteristics	Model 1 with student mediating variables	Model 3 with classroom / school characteristics
Intercept	**553.9 (2.8)**	**556.5 (2.3)**	**555.7 (3.4)**
Student-level variables			
Background variables			
Female	**-8.0 (2.2)**	**-12.4 (2.1)**	**-14.4 (2.9)**
Books in the home	**18.4 (1.4)**	**9.3 (1.4)**	**6.9 (1.9)**
SES	**16.4 (1.3)**	**8.3 (1.2)**	**4.6 (1.8)**
Ethnicity	-2.6 (1.5)	**-4.3 (1.4)**	**-4.4 (1.9)**
Family size	**-11.3 (1.2)**	**-5.9 (1.1)**	**-5.9 (1.6)**
Mediating variables			
Word knowledge		**42.8 (1.2)**	**40.2 (1.7)**
Positive attitudes towards science		**6.3 (1.1)**	**6.1 (1.5)**
Classroom / school variables			
Mean attitude to science			-1.7 (2.5)
Mean word knowledge			**8.7 (3.3)**
Mean SES			7.5 (5.1)
Time on science			-0.2 (2.5)
Rural			-4.2 (6.4)
Remote			18.9 (15.7)

Table 7.7 Estimates of Science Achievement: Schools, Classrooms and Students, Population 2, TIMSS

	Level 1 model – student background variables	Level 1 model – student background and mediating variables	Classroom, teacher, school and student model
Intercept	**527.7 (8.2)**	**555.8 (2.2)**	**545.5 (7.2)**
Student-level variables			
Background variables			
Female	**-17.0 (2.4)**	**-10.8 (2.1)**	**-18.6 (2.0)**
Books in the home	**14.7 (1.1)**	**9.4 (1.4)**	**8.9 (1.0)**
SES	**25.2 (1.3)**	**11.1 (1.2)**	**15.8 (1.2)**
Ethnicity	**-3.3 (1.0)**	**-3.4 (1.4)**	**-3.2 (0.9)**
Family size	**-6.0 (0.8)**	**-5.7 (1.2)**	**-4.2 (0.7)**
Mediating variables			
Word knowledge		**42.0 (1.2)**	**38.0 (1.1)**
Positive attitudes to science		**7.7 (1.1)**	**12.4 (1.0)**
Classroom / school variables			
Mean attitude to science			0.3 (1.5)
Mean word knowledge			**17.0 (1.5)**
Mean SES			**3.9 (1.6)**
Time on science			2.2 (1.6)
Rural			7.4 (3.6)
Remote			-2.5 (11.1)

Overall, these data suggest that secondary school science is somewhat biased in terms of gender, ethnicity and sociocultural and socioeconomic levels. There are, as in mathematics, definite benefits to be gained by students who are in classes with other similarly talented peers, and with those from a similar socioeconomic background. The analyses conducted were not able to investigate teacher effects on achievement, nor to a large extent on school effects, however these will be examined in the final section of this chapter, which looks at the other data available to us in TIMSS using the results of the multilevel analysis.

Effective learning environments for mathematics

In this section comparisons are made between those classes in which achievement levels are significantly higher than would be otherwise expected and those with significantly lower than expected achievement levels, other measured things equal. The focus is on mathematics achievement in both the Population 1 and Population 2 samples[10]. These classrooms were identified after allowing for all the factors included in the models represented in Tables 7.2 and 7.3. Technically, this means that the residuals from those models were used to identify the classrooms and schools of interest. In practical terms it means that the exploration is of learning environments that appeared to be effective (or ineffective) after allowing for differences in all of those factors identified in Tables 7.2 and 7.3. The residuals for each class and each school were ranked, and the top and bottom 20 per cent selected for analysis and comparison. This provided 58 classes at the lower level and 59 classes at the higher level for Population 1 and 62 classes at each level for Population 2.

In this part of the investigation a small number of classrooms and schools are involved and the analysis should be seen as exploratory. In recognition of this, differences that are statistically significant at the 10 per cent level are highlighted. This approach is consistent with that used in similar investigations based on data from the First International Science Study[11,12]. The overarching question addressed in the investigation is whether there is anything in approaches to teaching or general beliefs about mathematics and teaching mathematics that might shed some light on the differences between high and low performing classes.

Teacher attributes

Given that teacher gender, qualifications and teaching experience were already included in the analysis that identified the classrooms for this investigation, we would not expect to find many differences in teacher background. There are, however, a few differences that remain that warrant further investigation.

Table 7.8 shows the gender distribution for teachers at population 1 and 2 level. In the population 1 sample, 81 per cent of the lower achieving classes were taught by female teachers, compared to 67 per cent of the higher achieving classes. In the population 2 sample, 53 per cent of the lower achieving classes compared to 34 per cent of the higher achieving classes had female teachers. Both of these differences were statistically significant. Of course we have no way of knowing in which direction causality lies: are male teachers more often given higher achieving classes to teach or are their teaching methods somehow different?

Table 7.8 Gender Distribution of Teachers for Population 1 and Population 2, for High and Low Ranking Classes

Gender	Population 1 *Low ranking (%)*	Population 1 *High ranking (%)*	Population 2 *Low ranking (%)*	Population 2 *High ranking (%)*
Females	81	67	53	34
Males	19	33	47	66
	$\chi^2 = 3.9, p < .05$		$\chi^2 = 2.8, p < .10$	

Figure 7.2 shows the age distribution of teachers at both grade levels, for the higher and lower achieving classes separately. While these differences are not statistically significant within populations, there appears to be a difference between population 1 and population 2, in that there appears to be more of a likelihood of a young teacher teaching a high achieving class in a primary school than in a secondary school.

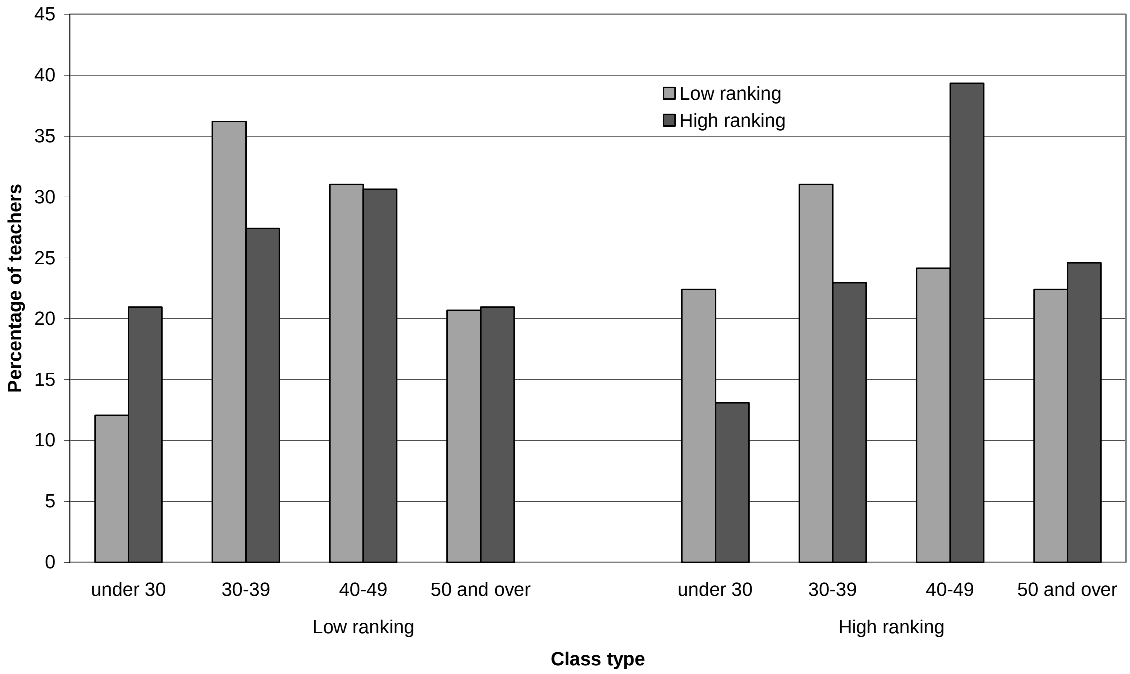

Figure 7.2 Teacher Age Distribution by Population And Type of Classroom

There were no other major differences in the backgrounds of the teachers of these two groups of classes for either the Population 1 or Population 2 samples. Of course, teacher gender, qualifications and teaching experience had already been included in the analysis that identified the classrooms for this investigation. Secondary teachers had a higher level of qualifications than their primary counterparts (70 per cent of secondary teachers held a bachelors degree or higher compared to 53 per cent of primary teachers). Around one-third of the teachers of both the low achieving and high achieving classrooms in the Population 1 sample held a university degree plus teacher training, while 17 per cent of the teachers of low achieving classes and 24 per cent of the teachers of high achieving classes held postgraduate degrees plus teacher training. Of the teachers in the Population 2 sample, 42 per cent of those teaching the lower achieving classes and 46 per cent of those teaching the higher achieving classes held a university degree plus teacher qualifications, while 23 per cent of the teachers of lower achieving classes compared to 32 per cent of those of higher achieving classes held a postgraduate degree plus teacher training.

Teachers' views of mathematics learning and mathematics

TIMSS queried teachers about the cognitive demands of mathematics, asking them to rate the importance of various skills for success on a three-point scale from not important to very important.

Teachers were asked to rate the importance of:

- remembering formulas and procedures;
- thinking in a sequential and procedural manner;
- understanding mathematical concepts, principles and strategies;
- thinking creatively;
- understanding how mathematics is used in the real world; and
- being able to provide reasons to support their solutions.

Table 7.9 and Table 7.10 show the level of agreement with each of these items for the two categories of classes for the Population 1 and Population 2 samples respectively.

Table 7.9 Differences between High and Low Achieving Classrooms in Teacher-rated Importance of Aspects of Mathematics Learning (%), Population 1

	Classroom type	Very important	Somewhat important	Not important
Remember formulas and procedures	High	41	53	6
	Low	*30*	*59*	*11*
Think in a sequential and procedural manner	High	63	31	6
	Low	75	25	0
Understand mathematical concepts, principles and strategies	High	77	23	0
	Low	*89*	*11*	*0*
Be able to provide reasons to support their solutions	High	78	20	2
	Low	*72*	*28*	*0*
Be able to think creatively	High	59	39	2
	Low	*76*	*24*	*0*
Understand how mathematics is used in the real world	High	84	16	0
	Low	*91*	*9*	*0*

None of these were significantly different between population 1 high achieving and low achieving classrooms. Most teachers, both in low achieving and high achieving classes, believe that the most important thing is that mathematics is set in context; that students understand how mathematics is used in the real world, and that students have an understanding of basic mathematical concepts and principles. The least important skill for the primary teachers was for students to simply remember formulae and procedures.

Table 7.10 Differences between High and Low Achieving Classrooms in Teacher-rated Importance of Aspects of Mathematics Learning (%), Population 2

	Classroom type	Very important	Somewhat important	Not important
Remember formulas and procedures	High	38	58	4
	Low	*48*	*50*	*2*
Think in a sequential and procedural manner	High	69	31	0
	Low	*82*	*18*	*0*
Understand mathematical concepts, principles and strategies	High	77	23	0
	Low	*79*	*21*	*0*
Be able to think creatively	High	*52*	*38*	*10*
	Low	62	34	4
Understand how mathematics is used in the real world	High	*52*	*42*	*6*
	Low	*55*	*38*	*7*
Be able to provide reasons to support their solutions	High	60	38	2
	Low	*82*	*18*	*0*

The only item on which there were significant differences between high and low achieving classes was for the item "*It's important for students to be able to provide reasons to support their solutions*". Perhaps surprisingly, this was ranked more highly by the teachers of the lower achieving classrooms than those of the higher achieving classes.

Teachers' perceptions about mathematics

Teachers were also asked to respond to a number of items that addressed their views about mathematics, student abilities in mathematics, and ways of teaching and learning mathematics. Teachers responded to these items on a four-point scale that ranged from *strongly agree* to *strongly disagree*. Figure 7.3 for primary schools and Figure 7.4 for secondary schools depict the percentage of teachers of high and low achieving classes who strongly agree or agree with each of the items.

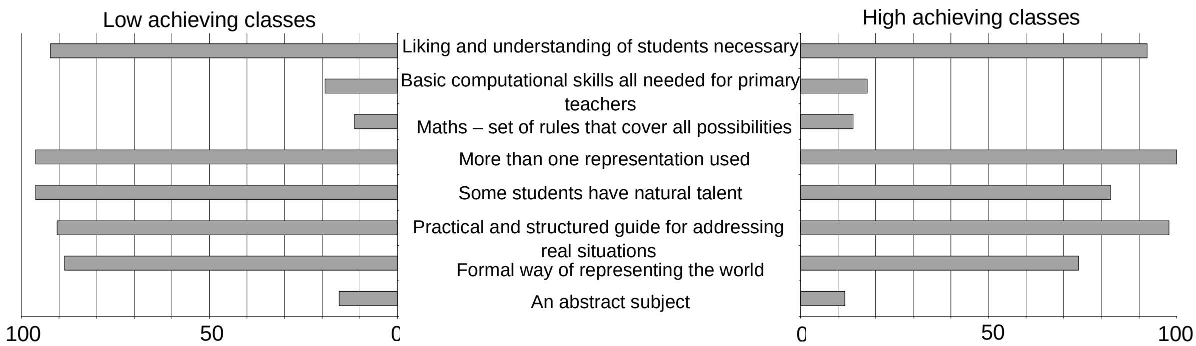

Figure 7.3 Teachers' Perceptions about Mathematics - Population 1

Teachers of both high and low achieving classes at both primary and secondary schools indicated a fairly practical view of mathematics, seeing it as essentially a way of modelling the real world. There was some variation in beliefs about this, with a much larger proportion of secondary teachers believing that mathematics is primarily an abstract subject.

There was also nearly uniform agreement across classrooms about the inherent nature of mathematical ability. More than 80 per cent of teachers of both high and low achieving classes, in primary and secondary schools, agreed or strongly agreed that some students have a natural talent for mathematics

Regarding perceptions about how to teach mathematics, teachers' opinions varied between high and low achieving classes, although this did not reach statistical significance. In general, more than 50 per cent of the teachers in lower achieving classes but only around 30 per cent of those teaching the higher achieving classes (in the population 2 sample) believed that more practice during class is an effective approach to help students having difficulty.

There was almost complete agreement amongst teachers that more than one approach should be used in teaching a mathematics topic. In all cases more than 90 per cent of teachers agreed with this approach.

Most teachers believed that more than basic computational skills were needed by primary school teachers, and most teachers agreed that liking and understanding students was also a prerequisite for effective mathematics teaching.

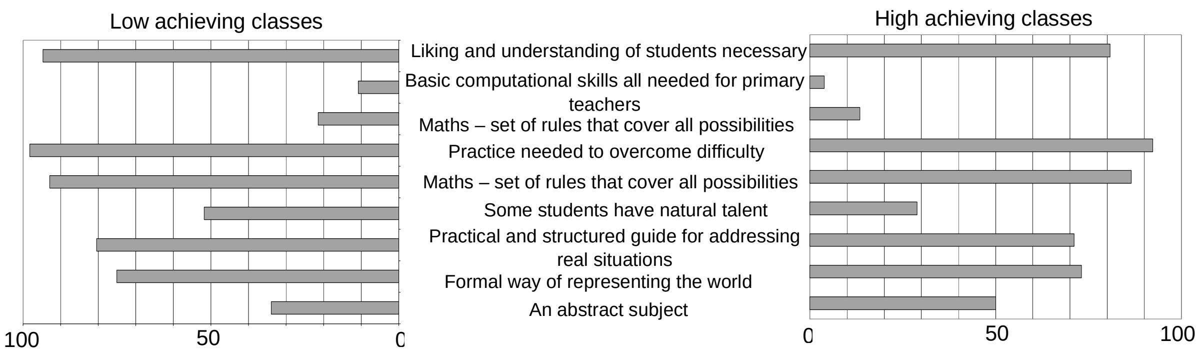

Figure 7.4 Teachers' Perceptions about Mathematics - Population 2

Teachers' satisfaction

A number of items addressed teachers' satisfaction with their jobs. These items included whether teaching was their first choice of career, whether they would change careers if given the opportunity, and whether they felt that society and their students appreciated their work. Relevant data summarising the responses of teachers from high and low achieving classrooms are shown in Figure 7.5.

No statistically significant differences were found at either primary or secondary level. There was a tendency for teachers in the higher achieving classes to be less satisfied with their jobs and to want to change careers. While a teacher's belief that students appreciated their work was generally lower for secondary teachers than primary teachers, it was particularly low for the teachers of low achieving classes.

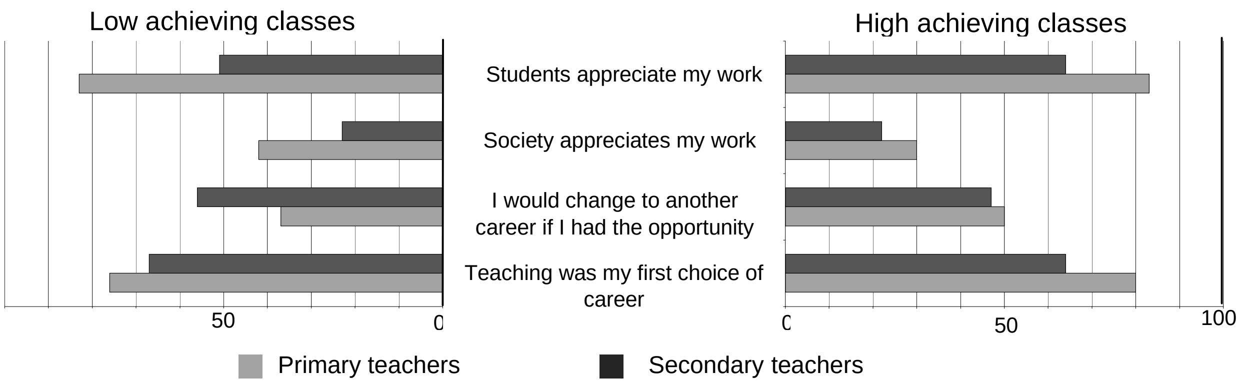

Figure 7.5 Satisfaction with Teaching in High and Low Achieving Classes

Limitations to teaching

The last area to be examined in this section of the report is the differences between teacher's perceptions of the extent to which a number of factors limit the way in which they teach their classes. These could be summarised as items regarding:

- students with differing needs (because of different abilities, disabilities or backgrounds);
- behavioural problems;
- parental issues;
- shortages; and
- low morale.

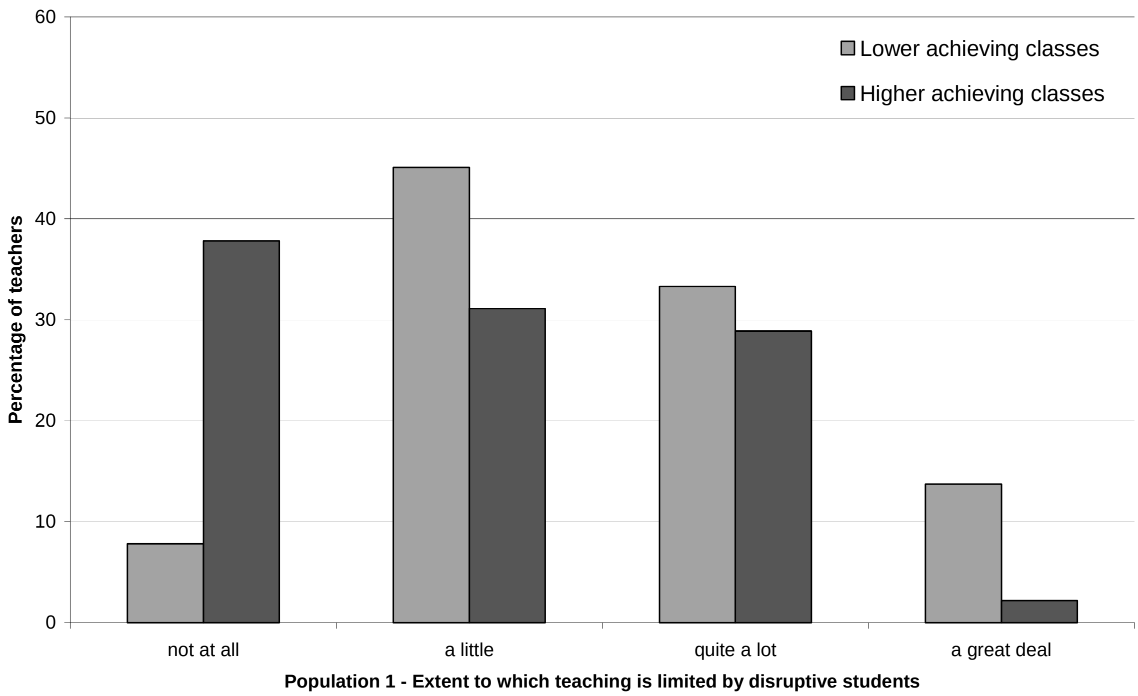

Figure 7.6 Population 1 Teachers' Beliefs about Limitation to Teaching because of Disruptive Students

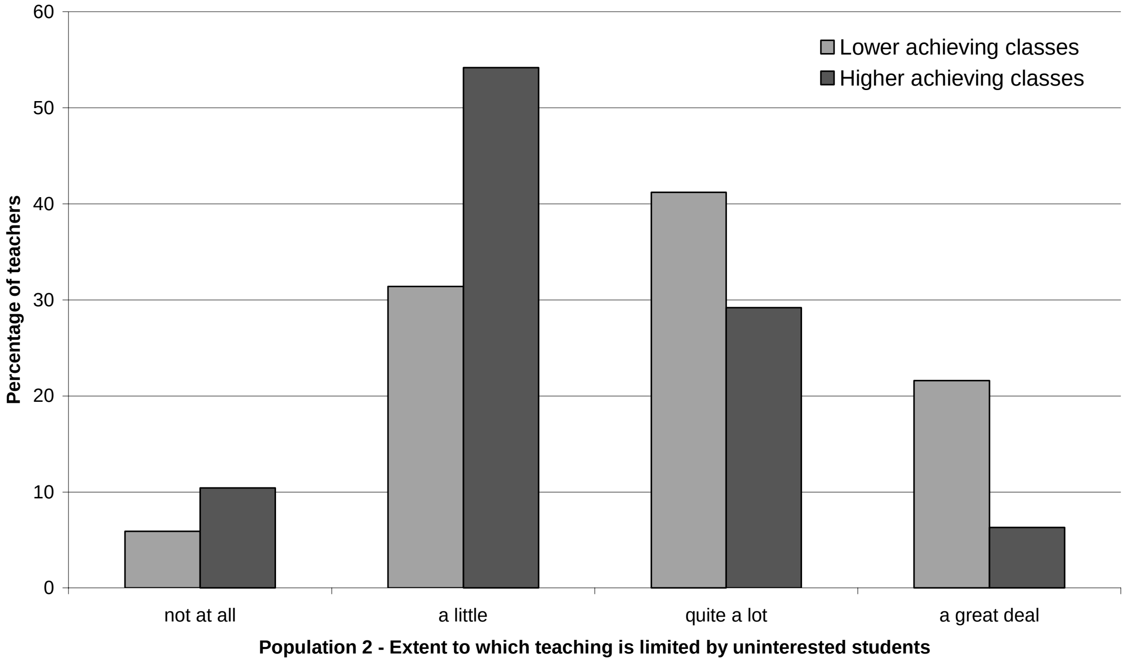

Figure 7.7 Population 2 Teachers' Beliefs about Limitation to Teaching because of Uninterested Students

For the primary school teachers, the only item on which teachers of high and low achieving classes differed significantly was the extent to which teachers believed that their teaching was limited by disruptive students. Figure 7.6 shows that, not surprisingly perhaps, disruptive students were more of a problem for the lower achieving classes.

For the population 2 teachers, there were only two significant differences between the perceptions of teachers of low achieving as compared to high achieving classes. Once again disruptive students were seen as more of a problem for teachers of lower achieving classes than for teachers of higher achieving classes, as shown in Figure 7.8, however there was also a significant difference in the perceived limiting effect of uninterested students (Figure 7.7).

More than 60 per cent of the teachers of low achieving classes believed that uninterested students limited their teaching in a fairly serious manner, whereas around half of this proportion of teachers of the higher achieving classes perceived such a problem.

While teachers and their methods of teaching are fundamental in building students' mathematical understanding, so are the school communities in which they teach. The multilevel analysis has already considered school location (rural, remote or urban), school size, the amount of time timetabled for mathematics, and school-level averages for socioeconomic status, there were a number of other items on the school questionnaire that were thought to be worthy of investigation.

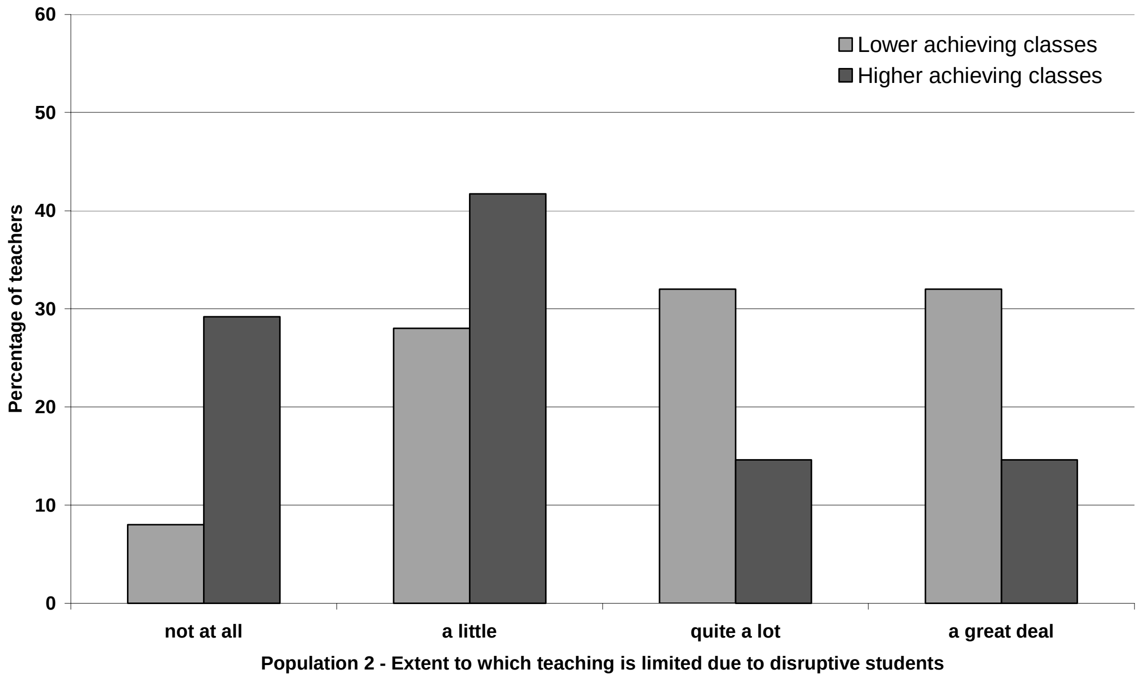

Figure 7.8 Population 2 Teachers' Beliefs about Limitation to Teaching because of Disruptive Students

Schools with effective classrooms

In general the classrooms that were identified as high achieving came from a number of schools (the 59 primary classrooms came from 40 different schools and the 62 secondary classrooms came from 43 different schools). This is consistent with the view that differences among classrooms account for more of the variability in achievement than differences among schools. However, within a given school there can be significant differences between classrooms in mathematics achievement. In a number of schools there were some classes that were classed as high achieving and some that were classed as low achieving. Clearly, in this case, the results are due to a combination of the background of the students (which may be associated with classroom grouping policies at the school), and the teacher.

Notwithstanding this observation there were some differences among the schools in which one or more effective classrooms were located. Due to the small number of cases involved, statistical significance will not be discussed. Instead, the focus will be on trends, which may point the way to areas for more in-depth investigation of such data.

Principals were asked the extent to which shortages in area listed in Table 7.11 affected the school's capacity to provide instruction. The percentages shown are the combined proportion that answered "some" or "a lot" to these items, reflecting that the shortage is perceived to be a substantial problem.

The largest differences between high and low achieving primary schools appears to be in the areas of basic provision of facilities (heating and lighting), and in the provision of computer hardware and software. While a shortage of computer hardware and software is seen as a major problem in both high and low achieving schools, it appears to be a greater problem in the lower achieving schools.

Table 7.11 Effect on Instruction of Shortages in Particular Areas, Population 1 and 2

	Primary schools		Secondary schools	
Shortage	*Low achieving schools (%)*	*High achieving schools (%)*	*Low achieving schools (%)*	*High achieving schools (%)*
Instructional materials	9	20	22	17
Budget for supplies	12	20	15	17
School buildings	34	29	44	18
Heating and lighting	22	6	25	11
Instructional space	34	34	37	17
Handicapped facilities	48	35	49	35
Computer hardware	59	37	54	44
Computer software	62	49	46	35
Calculators	12	9	12	6
Library materials	19	17	33	18
Audio-visual resources	28	29	39	18

Principals were also asked to what extent they dealt with particular problem behaviours in the school, and the proportion of principals dealing with the problem on a weekly or daily basis is provided in Table 7.12.

At the primary school level there are very few differences between high and low achieving schools. At the secondary school level the differences lie in the areas of cheating, vandalism, theft, and verbal or physical intimidation of other students or staff at the school.

Table 7.12 Percentage of Schools where Behaviour is dealt with on a Weekly or Daily Basis, Populations 1 and 2

	Primary schools		Secondary schools	
Behaviour	*Low achieving schools (%)*	*High achieving schools (%)*	*Low achieving schools (%)*	*High achieving schools (%)*
Arriving late at school	19	15	83	80
Absenteeism	9	11	56	51
Skipping classes	3	0	44	46
Violating dress code	na	na	71	73
Classroom disturbances	37	34	75	74
Cheating	0	3	17	3
Swearing	19	20	49	51
Vandalism	3	9	27	17
Theft	6	9	29	18
Intimidation/verbal abuse of other students	28	41	54	43
Injury to other students	19	26	22	14
Intimidation/verbal abuse of teachers	7	6	22	9
Tobacco use	na	na	39	34
Alcohol use	na	na	2	3

Table 7.13 Characteristics of Higher Achieving and Lower Achieving Schools, Populations 1 and 2

	Primary schools		**Secondary schools**	
	Low achieving	*High achieving*	*Low achieving*	*High achieving*
Average total enrolment	452	426	799	862
Teacher stability (% teachers teaching at the school for more than 5 years)	41	50	53	61
Student background				
% disadvantaged	22	20	18	23
% parents' primary education	7	3	6	4
% one-parent families	20	21	24	21
% learning problems	14	13	14	12
% health problems	9	4	8	6
% nutrition problems	7	4	4	4
% attended pre-school	70	75	na	na

Table 7.13 contains the averages for the low achieving and high achieving schools on a number of background variables that may be thought to influence student achievement in mathematics. Again, however, few conclusions are able to be drawn. The proportion of teachers who have taught at the school for longer than five years is slightly larger in the higher achieving schools than in the lower achieving schools, the proportion of parents with a primary school only education is slightly lower, and the proportions of students with health or nutrition problems is slightly lower.

However the differences that can be seen in Tables 7.12 and 7.13 are very small, when the sample is around 40 of each type of school. All these differences can indicate are directions for further investigation.

Summary

Through much educational research the search for school, classroom and teacher effects on student achievement through the analysis of survey data has proved elusive. In part this is because much survey data does not have the capacity to account for the effect of differences in students' ability, or prior achievement, on the outcome measures. In the data from the TIMSS it was possible to investigate influences on achievement after allowing for differences in ability. A measure of the Word Knowledge of students was able to be included in the analysis so as to identify the contribution of other factors to mathematics achievement. Although this is not the same as using longitudinal data including prior achievement it provides a good alternative.

A second requirement for the identification of influences on achievement is the use of methods of analysis that simultaneously take account of influences at individual, classroom and school level. The TIMSS data are so structured as to facilitate these forms of analysis and the method of analysis employed takes account of the influences at each level. As a consequence the results reported are of the 'other things equal' form. Most importantly the analyses have allowed for differences in student ability (as reflected in the Word Knowledge score which is the strongest predictor of mathematics achievement) but they also have allowed for the effects of other factors included in the analysis.

One set of conclusions from these analyses relate to background influences at the level of the individual student. Firstly, the analyses showed the expected influence of student social background (socioeconomic status, books in the home and family size) on achievement in both mathematics and science. However, this influence was much reduced when the Word Knowledge score was included in the analysis. In other words social background influences achievement both through its effect on developed ability (reflected in Word Knowledge) and through its direct effects. Lower socioeconomic status is associated with lower scores on the Word Knowledge test and this is in turn reflected in lower levels of achievement. Secondly, the analyses showed a small but significant difference between males and females in mathematics achievement in both population 1 and population 2. This appeared larger after allowance was made for differences in Word Knowledge scores. In other words females had higher scores on the Word Knowledge test than males but this was not reflected in their mathematics achievement in primary school, but in secondary school the opposite was apparent. Initially there was a gender difference but when allowance was made for Word Knowledge, this difference became non-significant. This means that males and females with similar levels of developed ability scored similarly on the mathematics test. In science the gap between males and females in achievement was wider than in mathematics, and evident at both primary and secondary school. Thirdly, there was no effect of non-English speaking background on achievement in mathematics and a very weak effect in science.

A second set of conclusions concerns the mediating influences: attitudes to mathematics or science and word knowledge. Having positive attitudes to the mathematics or science resulted in higher achievement in that area, even after allowing for the influence of developed ability. This was evident at both primary and secondary school level but was stronger at secondary school level. Although this is a student-level influence it has relevance for curriculum and teaching. It suggests that it is important to foster positive attitudes to mathematics and science if higher achievement outcomes are to be attained. An additional conclusion is that the influence of developed ability (word knowledge) is smaller at secondary level than primary school for mathematics. This suggests that mathematics is a more distinctive domain of achievement at this level of schooling and reflects school arrangements for more specialised teaching in that subject. The influence of developed ability was, however, stronger in science for secondary school than for primary school.

A third set of conclusions refers to school and classroom influences on achievement. Those were most evident in the analysis of mathematics achievement. The analyses suggest that school and classroom factors also influence mathematics achievement. At primary school level 30 per cent of the variation in achievement was associated with differences among schools or classrooms and at secondary school level the corresponding percentage was 43 per cent. For science the corresponding figures were 21 per cent at both primary and secondary school level. In other words school and classroom differences are a little more influential at secondary than primary school level, and a little more influential in mathematics than science. At both primary and secondary level the composition of classrooms (in terms of social background and developed ability) was an important influence on achievement. In the case of secondary schools, if the class was one with a high mean level of developed ability (higher class average Word Knowledge scores), mathematics and science achievement was higher. From a social learning perspective this is consistent with an interpretation that the resources that students bring to the classroom influence the learning that takes place and achievement. From a policy perspective it presents a dilemma: achievement can be enhanced for some but at the expense of others.

A fourth set of conclusions concerns the influence of teacher attributes, only examined in the mathematics analysis. In the multilevel analyses it was not possible to detect any overall influences of differences in either teacher background or approaches to teaching mathematics. In part this may be because it is hard to capture the detail of what happens in classrooms from teachers' answers to survey questions. It may also result from the form of variable-focused analysis typically employed. In the more detailed studies of unusually effective (and ineffective) classrooms it was suggested that features of schools related to student management (less lateness, absence, misbehaviour) may have been associated with higher levels of achievement. Those issues remain to be investigated further in more focused studies concerned with the clusters of classroom characteristics associated with different patterns of achievement.

Notes

[1] Raudenbush, S. & Willms, J.D. (eds) *Schools, Classrooms, and Pupils: International Studies of Schooling from a Multilevel Perspective.* Academic Press, San Diego, CA, 1991.

[2] Scheerens, J. & Bosker, R. *The Foundations of Educational Effectiveness*. Pergamon, Oxford, 1997.

[3] Willet, J. B. Measurement of change. In T. Husen & N. Postlethwaite (Eds) *Encyclopedia of Educational Research*. Pergamon, Oxford, 1994.

[4] Bosker, R. & Witziers, B. (1996) *The magnitude of school effects, or, does it really matter which school a student attends?* Paper presented at the annual meeting of the American educational research Association, New York, 1996.

[5] Number of possessions was measured by asking students which of the following possessions were in their homes: calculator, computer, dictionary, separate desk/table for study, personal bookshelves and books, separate wardrobe, dishwasher, CD or video player in their own room.

[6] Thorndike, R.L. *Reading Comprehension in Education in 15 Countries*. Almquist and Wiksell, Stockholm / John Wiley, New York, 1973.

[7] Rasbash, J., Browne, W., Healy, M., Cameron, B., & Charlton, C. (2000). *MLwiN (Version 1.10.0006)*. Multilevel Models Project, Institute of Education, University of London.

[8] Lokan, J., Ford, P., & Greenwood. *Maths and Science on the Line*. ACER, Melbourne, 1996.

[9] See Note 8.

[10] A similar investigation of effective science learning environments did not result in any clear patterns.

[11] Owen, J. *The Effects of Schools on Achievement in Science*. IEA (Australia) Report 1975:1. ACER, Melbourne, 1975.

[12] Wilson, A. *The Effects of Schools in Victoria on the Science Achievement of Junior Secondary School Students*. IEA (Australia) Report 1975:2. ACER, Melbourne, 1975.

Chapter 8

Conclusion

Australia was one of more than 40 countries that took part in the Third International Mathematics and Science Study (TIMSS). From the study there have been several international reports, national reports from participating countries and a growing range of research papers published. One of the benefits of international studies of achievement is that the wider variation in practice and policy enables the investigation of organisational and curriculum-related issues that could not easily be investigated in a single school system or country. Naturally occurring differences among education systems provide a basis for studying relationships of such factors with student achievement. In addition to the potentials of international analyses these studies also provide the possibility of analyses within each country. National analyses do not have such wide variation in practice and policy but they provide the possibility of using that variation for analyses within a context that facilitates local interpretation.

Variability in achievement

There is considerable variation in achievement within Australia. Although Australian students performed comparatively well at both the Population 1 (primary school) and Population 2 (early secondary school) level there was a large variation among students in achievement. An analysis of the within-country variability of mathematics achievement has shown the dispersion of scores in Australia to be relatively large. The standard deviation for mathematics achievement among Year 4 students was the second largest of participating countries and for Year 8 mathematics it was the fifth largest[1]. There was also a considerable variation in science achievement at these levels. The challenge and the opportunity provided by these data are to identify the factors that contribute to these variations.

Among secondary schools (Population 2) some 57 per cent of the explained variance in mathematics achievement was associated with differences among students in classrooms and 43 percent with differences among schools and classrooms (15 and 28 per cent respectively). In primary schools (Population 1) some 66 per cent of the explained variance in mathematics achievement was associated with differences among students within classrooms and 34 per cent with differences among schools and classrooms (9 and 25 per cent respectively). In other words there were greater differences among schools at secondary than primary level. Where there is a relatively higher percentage of the variance in mathematics achievement at student level it is an indication that schools are relatively more uniform in achievement. Thus these data indicate there are more differences among schools at secondary than primary level but at both levels there are greater differences among classrooms than among schools.

From an international perspective Australia was one of a few countries in which the student level variance in Year 8 mathematics was relatively low (it was less than 60 per cent in the USA, the Netherlands, Belgium, Germany, Hong Kong, and Switzerland)[2]. In several of these countries this variability among schools at Year 8 level is associated with differentiation between types of school (eg Germany or the Netherlands) or tracking within schools (eg the United States of America).

Student aptitudes and attitudes

Among individual students differences in achievement in mathematics and science was influenced by the verbal ability of students (and strongly influenced in the case of mathematics). In other words performance in these particular domains is associated with the students' levels of developed general ability. It is therefore important to allow for these differences when identifying other factors that contribute to mathematics and science achievement. Students' dispositions were also important influences on their achievement in mathematics. After allowing for differences in verbal ability background and other factors, students who had favourable attitudes to mathematics or science in school, and students who saw these disciplines as important, had higher achievement in them. This means that it is important for those developing curricula, and for teachers planning and teaching lessons, to give attention to interest that is generated by those curricula and those lessons.

Student background

Student socioeconomic background influenced achievement in mathematics and science both directly and through its link to verbal ability. Lower socioeconomic status is associated with verbal ability scores and this is in turn reflected in lower levels of achievement in mathematics and science. In primary school (Population 1) the direct effect was a little less than in secondary school (Population 2) and correspondingly the transmitted influence was a little greater. It is important to recognise that both paths are evident at both levels of school. Gender had small effects on achievement in science (girls scored lower) and almost none in mathematics. However, it did appear that girls had lower levels of mathematics achievement than would have been expected on the basis of their verbal ability. There was no effect of ethnicity on mathematics or science achievement either before, or after, making allowance for other potential influences. However, students of non-English speaking background did more homework than other students.

Classrooms

The composition of classrooms (in terms of social background and developed ability) was an influence on achievement. Students in classrooms where there was a high average level of verbal ability and high levels of socioeconomic background performed better in mathematics, after allowing for the influence of their own socioeconomic level and ability. In the case of secondary schools, if the class was at the upper level in an organisational arrangement based on ability grouping, achievement was higher (again it is important to note that this was after allowing for differences in ability at both student and classroom level). From a social learning perspective this is consistent with an interpretation that the resources that students bring to the classrooms influence the learning that takes place and achievement. It is also consistent with the proposition that teaching is more effective when it is pitched at a level that is appropriate for most students in the group (in the region that just extends what students can already do). From the perspective of how learning is organised in a school, this presents a dilemma: achievement can be enhanced for some but at the expense of others. This raises once again the issue of how to teach effectively to classes containing a wide range of aptitudes.

Teachers

From two different results from the analysis of mathematics achievement there is an indication that some attributes of teachers influence the achievement of students. In primary schools it appeared that mathematics achievement was higher for the classes of male teachers than for the classes of female teachers. Several interpretations of this result are possible but one that seems plausible is that the result may reflect differences in the emphasis on mathematics in the work programs of teachers. In the common organisational pattern of primary schools there is scope for teachers to vary the emphasis on different learning areas. Such variations could reflect their own views about mathematics and its importance or their confidence in teaching mathematics. In secondary schools it appeared that mathematics achievement was higher in the classrooms of more experienced teachers. This has been an enduring belief about teaching that has not been consistently demonstrated. This result suggests that the benefits of experience may apply in a field such as mathematics at secondary school level even if it is not necessarily the case for all learning areas.

Approaches to teaching

In the large-scale analyses it was not possible to detect any overall influences of differences in approaches to teaching mathematics, after other factors were taken into account. Of course, it is hard to capture the detail of what happens in classrooms from teachers' answers to survey questions. However, in the more detailed studies of unusually effective (and ineffective) classrooms, there emerged some suggestions of factors that might have influenced those differences in mathematics achievement. One of these suggestions involved the behavioural manifestations of school climate. The incidence of lateness, absence and misbehaviour tended to be higher in ineffective than effective classrooms. A second of these suggestions involved the extent to which teachers emphasised algorithms and procedures as important. Such an emphasis does not have to be at the expense of other aspects of mathematics teaching and appears to have been more evident in higher achieving classrooms than lower achieving classrooms.

Most of the analyses in this report have focussed on the overall scores in mathematics and science. It is possible that particular teaching approaches and curriculum patterns have effects on areas of mathematics and science. It is also possible that it is appropriate combinations of influences, rather than influences operating independently, that have an impact on achievement.

Notes

[1] W. Schmidt, C. McKnight, L. Cogan, P. Jakwerth and R. Houang. *Facing the Consequences: Using TIMSS for a Closer Look at US Mathematics and Science Education*. Boston, Kluwer, 1999, pp163-171.

[2] W. Schmidt, C. McKnight, L. Cogan, P. Jakwerth and R. Houang. *Facing the Consequences: Using TIMSS for a Closer Look at US Mathematics and Science Education*. Boston, Kluwer, 1999, pp173-175.

Appendix 1

Bibliography: IEA First and Second Mathematics and Science Studies

First International Mathematics Study

Australian publications

Keeves, J. P. (1966). *Evaluation of Achievement in Mathematics*. Australian Council for Educational Research, Melbourne.

Keeves, J. P. (1968). *Variation in Mathematics Education in Australia*. Australian Council for Educational Research, Melbourne.

Keeves, J. P. & Radford, W. C. (1969). *Some Aspects of Performance of Mathematics in Australian Schools*. Australian Council for Educational Research, Melbourne.

International publications

Husén, T. (ed.) (1967). *International Study of Achievement in Mathematics: A Comparison of Twelve Countries* (Vols 1 and 2). Almqvist & Wiksell, Stockholm/John Wiley, New York.

Second International Mathematics Study

Australian publications

Rosier, M. J. (1980). *Changes in Secondary School Mathematics in Australia, 1964-1980.* Australian Council for Educational Research, Melbourne.

International publications

Garden, R. (1987). The Second IEA Mathematics Study. *Comparative Education Review,* **31**(1), 47-68.

Travers, K. J. & Westbury, I. (1989). *The IEA Study of Mathematics I: International Analysis of Mathematics Curricula*. Pergamon, Oxford.

Robitaille, D. F. & Garden, R. A. (eds) (1989). *The IEA Study of Mathematics II: Contexts and Outcomes of School Mathematics*. Pergamon, Oxford.

Burstein, L. (ed.) (1993). *The IEA Study of Mathematics III: Student Growth and Classroom Processes.* Pergamon, Oxford.

First International Science Study

Australian publications

Rosier, M. J. & Williams, W. H. (1973). *The Sampling and Administration for the IEA Science Projects in Australia 1970: A Technical Report*. IEA Australia Report 1973:8. Australian Council for Educational Research, Melbourne.

International publications

Comber, L. C. & Keeves, J. P. (1973). *Science Education in Nineteen Countries*. International Studies in Evaluation I. Almqvist & Wiksell, Stockholm/John Wiley, New York.

Second International Science Study

Australian publications

Rosier, M. J. (1987). *An Analysis of Science Curricula in Australia*. Second International Science Study, Australia, Report Series: No. 1. Australian Council for Educational Research, Melbourne.

Rosier, M. J. & Banks, D. K. (1990). *The Scientific Literacy of Australian Students: Science Achievement of Students in Australian Primary and Lower Secondary Schools*. ACER Research Monograph No. 39. Australian Council for Educational Research, Melbourne.

International publications

Rosier, M. J. (1987). The Second International Science Study. *Comparative Education Review*, **31**(1), 106-28.

International Association for the Evaluation of Educational Achievement (1988). *Science Achievement in Seventeen Countries: A Preliminary Report*. Pergamon, Oxford.

Appendix 2

Rationale for Item Response Theory (IRT) techniques used in TIMSS

For readers who would like more information on the Item Response Theory (IRT) techniques used in TIMSS, a detailed discussion is provided by Adams, Wu and Macaskill in the international TIMSS Technical Report series.[1] The following paragraphs attempt to present a simplified explanation. The explanation applies equally to the construction of composite variables from responses to collections of test items and to collections of questionnaire items, as carried out for the further stages of this book.

In any research study of human characteristics such as this one, the relationships explored are actually relationships between so-called 'latent variables'. With a few exceptions, the characteristics are not actually observable physical ones, but abstract characteristics that are inferred from responses to aspects that are presumed to be manifestations of them. In the current context, mathematics and science achievement are latent variables. The students are assumed to possess amounts of mathematics and science knowledge and skills, and these amounts of achievement are reflected in their performance on collections of test items. It is important to recognise that the item responses, as a set, are reflections of the underlying achievement level and are not themselves the achievement level.

In practical settings, such as TIMSS, it is not possible to have access to individuals' scores on latent variables. The manifestations (item responses) have to be used to infer those scores. Latent trait theory, often referred to as 'item response theory' (or, more correctly, 'item response modelling') is a well-known and well-developed methodology for making the inferences of students' levels on a latent variable from collections of categorical responses to test or questionnaire items (e.g. right/wrong; fully right/partly right/wrong; strongly disagree/disagree/agree/strongly agree).

Categorical responses are themselves approximations, and are therefore subject to measurement error. To reach a better understanding of this point, imagine the impossibility of predicting a student's science achievement from his or her response to a single science item, scored as 'right' or 'wrong'. The single item can at best place individuals at one of two locations on the science achievement latent variable. One location is for the students who answered correctly, the other for those who answered incorrectly. But clearly it will not be the case that all of the students who answered correctly have exactly the same level of science achievement, nor will it be the case that all who answered wrongly have the same level. The accuracy with which individuals' levels on the latent variable can be shown depends on the number of manifestations that are used in making the inference. The amount of error in the inference is called 'measurement error'.

In a study like TIMSS, the amount of measurement error in each variable adds considerably to the complexity of the data analyses. All of the variables, including the mathematics and science scales, are measured with measurement error that cannot be ignored, otherwise potentially misleading results are likely to be obtained.[2]

Recent advances in 'latent trait' theory have led to the development of procedures that can be used to largely overcome the problems and potential for incorrect interpretations that are introduced by ignoring measurement error when doing data analysis.[3] These methods were implemented in the TIMSS international data analysis and in the preparation of the international and the Australian national reports.

The implementation of these methods for the present reports required the use of specialist IRT scaling software[4] to derive 'plausible values' of the students' mathematics and science achievement, which are explained below.

Plausible values

Each student at Population 2 responded to only about 70 items from the total pool of over 150 items. 'Plausible values' allow each student to be assigned a score as if he or she had attempted all of the items. They minimise measurement error because they take into account large amounts of information (the students' responses to questionnaire items as well as to the test items). They have been used in the US National Assessment of Educational Progress (NAEP) since the early 1980s, and are ideal for a study like TIMSS where the main goal is to produce the most accurate estimates of population proficiency. (They are not suitable for use for decisions about individual students, however.)[5]

The scores used as measures of achievement in this book are plausible values scores.

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1 R. Adams, M. Wu & G. Macaskill, Scaling methodology and procedures for the mathematics and science scales. In M. O. Martin & D. L. Kelly (eds), *Third International Mathematics and Science Study Technical Report Volume II: Implementation and Analysis*. Boston College, Chestnut Hill, Massachusetts, 1997, pp 111-145.

2 P. P. Biemer, R. M. Groves, L. E. Lyberg, N. A. Mathiowetz & S. Sudman, (eds), *Measurement errors in surveys.* John Wiley & Sons, New York, 1991; and

W. A. Fuller, *Measurement error models.* John Wiley & Sons, New York, 1997.

3 See Note 1, and

R. J. Mislevy, Randomization-based inference about latent variables from complex samples. *Psychometrika*, **56**, 177-196.

4 M. L. Wu, R. J. Adams & M. R. Wilson, M. R., *ConQuest*. Australian Council for Educational Research, Melbourne, 1998.

5 A. E. Beaton & E. J. Gonzalez, *NAEP Primer*. Boston College, Chestnut Hill, Massachusetts, 1995.

Appendix 3

Results of Factor Analyses of Teacher Variables

Table 1 Factor Loadings, after Rotation, of Mathematics Classroom Practices and Teacher Beliefs, Population 1

	Component					
	1	**2**	**3**	**4**	**5**	**6**
How often do students:						
work in groups, with assistance from the teacher	.660					
work in groups, with no assistance	.620					
work on problems	.600					
do tasks where they must explain their reasoning	.493					
do tasks where they must analyse relationships	.419					
work as a class, students responding to each other	.403	.344				
use computers to solve problems	.355				.308	
work together as a whole class, with the teacher		.622				
practice computation		.596				
work individually, with assistance from the teacher		.588				
How often does the teacher:						
discuss a response with the class to reach a correct one	.331	.505				
help a student reach a correct response		.503				
How much does the teacher agree that mathematics:						
is a practical and structured guide to the real world			.639			
requires thinking that is sequential and procedural			.553			
is a formal representation of the real world			.535			
requires students to understand concepts			.477	.316		
How often does the teacher:						
use more than one representation for a concept			.378			
How much does the teacher agree that mathematics:						
should be learned as a set of algorithms or rules				.586		
requires only basic computational skills of the teacher				.554		
requires individual practice to overcome difficulties				.457		
requires students to remember formulae				.430		
is primarily an abstract subject				.345		
How much does the teacher agree that students:						
should give reasons for their solutions in mathematics					.744	
should understand how mathematics is used in the world					.700	
should develop creative solutions in mathematics					.487	
How often does the teacher:						
correct a student in front of the class					-.403	
How much does the teacher agree that:						
his/her work is appreciated by students						.641
his/her work is appreciated by society						.639
he/she would change career if had the opportunity						-.517

Items concerning mathematics teaching that failed to load on any of the six factors, Population 1:

Teacher beliefs:

- Some students have a natural talent for mathematics, others do not.
- A liking for and understanding of students are essential for teaching mathematics.

Classroom practices:

- How frequently are students asked to write equations?
- How often do students work individually in mathematics lessons, with no assistance?
- How often does the teacher call on another student who’s likely to give the correct response?

Attitude to profession:

Whether teaching was the teacher’s first choice when beginning teacher training or university.

Table 2 Factor Loadings, after Rotation, of Mathematics Classroom Practices and Teacher Beliefs, Population 2

	Component				
	1	**2**	**3**	**4**	**5**
How much does the teacher agree that mathematics:					
should be learned as sets of algorithms or rules	-.540				
requires only basic computational skills of the teacher at primary level	-.437				
How often does the teacher:					
ask students to explain the reasoning behind an idea	.530				
ask questions to help a student reach a correct response	.443				
discuss a response with the class to reach a correct one	.438	.362			
use more than one representation for a concept	.438				
How much does the teacher agree that:					
a liking for and understanding of students are essential for teaching maths	.378				
mathematics requires students to remember formulae		.513		-.320	
How often do students:					
work individually, with assistance from the teacher	.346	.476			
work individually, without assistance from the teacher		.458			
practise computational skills		.441			
How much does the teacher agree that:					
students having difficulty need more practice in class		.393			
How often does the teacher:					
correct a student in front of the class		.390			
ask other students to respond, following an incorrect answer		.373			
How much does the teacher agree that mathematics:					
requires students to understand its real world uses			.690		
is a practical guide for addressing real world problems			.563		
requires students to provide reasons for their solutions			.544		
requires students to be able to think creatively			.503		
requires students to understand mathematical concepts and ideas			.407		.386
is primarily a formal way of representing the world			.394		
How often do students:					
work in small groups, without assistance from the teacher				.650	
work in small groups, with assistance from the teacher				.540	
use computers to solve problems				.383	
work together as a class, responding to each other				.373	
do tasks where they must analyse relationships using tables, charts or graphs				.360	
work on problems that have no immediate solution				.318	
How much does the teacher agree that:					
some students have a natural talent for maths, some don't				-.413	
his/her work is appreciated by students					-.602
his/her work is appreciated by society					-.541
he/she would change career if had the opportunity					.480
teaching was his/her first choice of career					-.326

Items concerning mathematics teaching with equivalent loadings on more than one factor, Population 2:

Classroom practices:

How often the students work together as a class, with the teacher teaching the whole class (loaded about .43 on both factors 1 and 2)

Teacher beliefs:

To be good at mathematics, it is import for students:

- to think in a sequential and procedural manner (loaded about .3 on factors 2, 4 and 5)

Items concerning mathematics teaching that failed to load on any of the five factors, Population 2:

Classroom practices:

How often students are asked to write equations to represent relationships.

Teacher beliefs:

How much the teacher agrees that mathematics is an abstract subject?

Table 3 Factor Loadings, after Rotation, of Science Classroom Practices and Teacher Beliefs, Population 2

	Component				
	1	2	3	4	5
How often does the teacher:					
ask students to work on problems	.594				
ask students to explain the reasoning behind an idea	.570				
ask questions to help a student reach a correct response	.545				
ask students to write explanations	.479				
ask students to organise events of objects	.436				
ask students to analyse relationships using tables, charts or graphs	.374				
ask other students to respond, following an incorrect answer	.370				
How often do students:					
work together as a class, responding to each other	.589				
work in small groups, with assistance from the teacher	.427				.355
How much does the teacher agree that:					
science requires students to remember formulae		.651			
science requires students to think in a sequential manner		.524	.304		
students need prescriptive directions for doing science experiments		.482		.348	
some students have a natural talent for science, some don't		.413			
focussing on rules leads to a belief that science is about memorising procedures		-.334			
How often does the teacher:					
correct a student in front of the class		.466			
ask another student to get the correct response		.396			.315
How often do students:					
work together as a class, teacher teaching the whole class		.306			
How much does the teacher agree that science:					
requires students to provide reasons for their solutions			.747		
requires students to understand its real world uses			.709		
requires students to be able to think creatively			.678		
requires students to understand scientific concepts		.325	.416		
is a practical guide for addressing real world problems				.576	
is primarily a formal way of representing the world				.375	
is primarily an abstract subject				-.337	
How often do students:					
use computers to solve problems				-.320	
work in small groups, without assistance from the teacher	.420			.457	
work individually, without assistance from the teacher	.328			.369	
How much does the teacher agree that:					
his/her work is appreciated by society					.718
his/her work is appreciated by students					.715
he/she would change career if had the opportunity					-.608

Items concerning science teaching that failed to load on any of the five factors, Population 2:

Classroom practices:

How often students are often asked to work individually with assistance from the teacher?

Attitude to profession:

Whether teaching was the teacher's first choice when beginning teacher training or university

Teacher beliefs:

How much the teacher agrees that:

- If students get into debates in class about ideas or procedures covering the sciences, it can harm their learning.
- Students see a science task as the same task when it is represented in two different ways (picture, concrete material, symbol set etc)
- A liking for and understanding of students are essential for teaching science.