Examining the evidence: Science achievement in Australian schools in TIMSS 2002

(TIMSS Australia Monograph no 7)

Sue Thomson and Nicole Fleming

Australian Council *for* Educational Research

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Executive summary

The *Trends in International Mathematics and Science Study* (TIMSS 2002/03) is the latest in a series of international studies of mathematics and science, conducted under the aegis of the *International Association for the Evaluation of Educational Achievement* (IEA). These studies extend back to the First International Science Study (FISS) that was conducted in secondary schools in 19 countries in 1970. Two international studies of mathematics education were conducted in 1964 and 1980-1982. The present study is the third combined mathematics and science study in which Australia has participated since 1994; others being the Third International Mathematics and Science Study (TIMSS 1994/95), and the partial repeat of TIMSS at Year 8 in 1998/99 (TIMSS 1998/99).

Australia's participation in TIMSS provides an opportunity to continue to build a comprehensive picture of trends in, and patterns of, achievement in mathematics and science for students in Year 4 and Year 8. Countries differ in the way their school education is organised, in the approaches adopted to teaching, their curricula, the preparation of their teachers, in their expectations of students, and in many other factors potentially related to effective learning. Those 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 opportunities to study relationships of such factors with student achievement. The sequence of studies that have followed provide an opportunity to study changes over time as well as differences among countries.

This volume, *Examining the evidence*, analyses and interprets the Australian science data collected as part of the TIMSS study. Another Australian report, *Summing it up* (Thomson & Fleming, 2004), presents the mathematics results. Where appropriate, these reports make comparisons with the results of a number of countries and the international average to better understand the Australian achievement and context.

Research design

Building on previous IEA studies, TIMSS uses the curriculum as the major organising concept in considering how educational opportunities are provided to students and how students use these opportunities. It considers three levels of the curriculum in relation to the context in which they operate. The first level refers to science that it is intended that students should learn and the educational system within which that curriculum is realised. This is called the *Intended Curriculum*. The second level refers to what is taught in classrooms, who teaches it and how it is taught; the *Implemented Curriculum*. The third level refers to what students have learned and their attitudes towards what they have learned; the *Attained Curriculum*.

From this broad framework TIMSS develops science tests to describe what students have learned and questionnaires to find out about what is intended to be taught and about how it is actually taught in classrooms. These instruments are based on assessment frameworks that are developed after extensive analysis of national curricula with input from an international panel of science and assessment experts and review by the *National Research Coordinators* (NRCs) in each country. This ensures that goals of science education regarded as important in a significant number of countries are included and that what is assessed links to previous studies as well as being oriented to future developments in science education.

So that the full range of the assessment framework is covered TIMSS divides the assessment material among students using a matrix sampling approach. This involves dividing the material among a set of student test booklets with each student completing just one of the booklets. Science items are grouped in 14 blocks that are used to build the 12 booklets with each booklet containing six blocks of mathematics and science items (there are also 14 blocks of mathematics items). At Year 8 each block contains 15 minutes of assessment items and at Year 4 each block contains 12 minutes of assessment items. Thus each student in Year 8 completes 90 minutes of testing and each student at Year 4 completes 72 minutes of testing. The total amount of combined mathematics and science material covered is equivalent to 420 minutes of testing at Year 8 and 336 minutes of testing at Year 4. The questionnaire that students complete takes 30 minutes.

Who is assessed?

TIMSS 2002/03 focuses on two populations of students. Population 1 is students in Year 4. In most countries it is the year level that contains most nine-year-olds. Population 2 is students in Year 8. In most countries this is the year level that contains most 13-year-olds.

TIMSS 2002/03 took place in 46 countries around the world. Population 2 students were assessed in all participating countries. In 25 of the participating countries, Population 1 students were also assessed. The testing took place at the end of the school year, which was October-November 2002 in the southern hemisphere and May-June 2003 in the northern hemisphere.

TIMSS 2002/03 used a two-stage sampling procedure to ensure a nationally representative sample of students. In the first stage, schools were randomly selected to represent states and sectors. In the next stage, one mathematics class of Year 4 or Year 8 students was randomly selected to take part in the study.

In Australia, 10,030 students in 414 schools participated in the main sample of TIMSS 2002/03. In addition, in Australia, an extra sample of Year 9 students in participating schools in Queensland, South Australia, Western Australia and the Northern Territory was collected to enable comparisons with data collected in TIMSS 1994/95 and 1998/99. An extra sample of Indigenous students in all participating schools was also collected. These extra samples will provide data for further analysis on trends in mathematics and science achievement, and a more detailed examination of the achievements of Australia's Indigenous students.

What is assessed?

TIMSS tests are intended to generate achievement data that are valid for their intended purpose and reliable. They include items that require students to select a response from a set of multiple choices and questions that require students solve a problem and construct a response in an open-ended format. The items balance across five content domains (life science, chemistry, physics, earth science, and environmental science) and three cognitive domains (factual knowledge, conceptual understanding, and reasoning and analysis). Of course some items span more than one of the content domains and the balance across domains differs between Year 4 and Year 8. In TIMSS 2002/03 the intended balance was as shown:

Science content domains	Year 4	Year 8
Life science	45%	30%
Physical science (Y4)	35%	
Chemistry (Y8)		15%
Physics (Y8)		25%
Earth science	20%	15%
Environmental science (Y8)		15%

Science cognitive domains	Year 4	Year 8
Factual knowledge	40%	30%
Conceptual understanding	35%	35%
Reasoning and analysis	25%	35%

How are results reported?

Results are reported as average scores with the standard error, as distributions of scores, and as percentages of students who attain the international benchmarks, for countries and specific groups of students within Australia. The international benchmarks were developed using scale anchoring techniques. Internationally it was decided that performance should be measured at four levels: the '*Advanced International Benchmark*', which was set at 625; the '*High International Benchmark*', which was set at 550; the '*Intermediate International Benchmark*', which was set at 475; and the '*Low International Benchmark*', which was set at 400.

Australia s performance in TIMSS Science 2002/03

Some highlights from the TIMSS 2002/03 science results are given below. Differences are only mentioned if tests of statistical significance showed that the differences were likely to indicate real differences.

Performance internationally

- Australian students acquitted themselves well in science, with the performance of Australian students at both year levels significantly higher than the international average.
- The highest-scoring countries at both year levels were Singapore and Chinese Taipei.
- There was no significant change in average scale score at Year 4 levels for Australia from TIMSS 1994/95 to 2002/03. However, a number of other countries show a significant improvement over this period, raising their position relative to that of Australia.
- The average score for Year 8 science significantly increased from TIMSS 1994/95 to 2002/03. The performance of some countries which were previously similar to Australia are now significantly lower than Australia.

Performance on international benchmarks in science

- Nine per cent of Australian Year 4 students reached the advanced international benchmark, 38 per cent reached the high international benchmark, 74 per cent reached the intermediate international benchmark and 92 per cent reached the low international benchmark. These proportions are higher than the international average for each benchmark.
- Nine per cent of Australian Year 8 students reached the advanced international benchmark, 40 per cent reached the high international benchmark, 76 per cent reached the intermediate international benchmark and 95 per cent reached the low international benchmark. These proportions are higher than the international average for each benchmark.

Performance in the science content areas

- Australian Year 4 students' achievement was significantly higher than the international average in all content areas. Average achievement is fairly similar across all content areas.
- Australian Year 8 students' achievement was significantly higher than the international average in all content areas. *Chemistry* is clearly the weakest achievement area, followed by *physics*.

Performance of males and females

- There were no significant gender differences in overall science achievement in Australia at Year 4. However, in Year 8, males scored a significant 20 score points higher than females.
- Year 4 females outperformed males in *life science*. At Year 8, males significantly outperformed females in *chemistry*, *physics*, *earth science* and *environmental science*.

Performance of the Australian states and territories

- Year 4 students in all states except the Northern Territory performed at a level higher than the international average. The Northern Territory achieved at the international average. The average score of students in the Australian Capital Territory was the only state average that was significantly higher than the national average. The average achievement of the other states was not significantly different from each other, except for that of the Australian Capital Territory and Western Australia.
- Scores for Year 8 students in New South Wales were significantly higher than those for Victoria and the Northern Territory; and scores for students in the Australian Capital Territory were also significantly higher than those for students in the Northern Territory. The achievement level of students in most states was significantly higher than the international average. The only exception to this was the Northern Territory, where there was no significant difference between the average for the state and the international average.
- Out of all the states, the Australian Capital Territory had the greatest proportion of Year 4 students attaining each of the international benchmarks. The Northern Territory had the least proportion of students reaching the low international benchmark.

- New South Wales had the greatest proportion of Year 8 students reaching the advanced international benchmark, whereas the Australian Capital Territory had the greatest proportion reaching the low international benchmark. The Northern Territory had the least proportion of students reaching either the advanced international benchmark or the low international benchmark.

Student background characteristics

- Year 8 students were asked the highest level of education reached by their mother and father. The highest of these was used as the parental education variable, and achievement in science was found to be higher for students whose parents had completed a university degree or higher.
- At both year levels there was a clear and strong relationship between books in the home and achievement in science. Home education resources were also found to be positively related to science achievement.
- Overall, the achievement of Indigenous students at both year levels was significantly lower than that of non-Indigenous students. For Year 4 students the difference between the scores of the two groups was slightly larger than in TIMSS 1994/95. However, at Year 8, the difference between the scores of the two groups was less than in TIMSS 1994/95.
- The relationship between science achievement and language background was not clear. At Year 4 students who spoke English at home achieved at a significantly higher level than those who did not, while for Year 8, these differences were not apparent.

Out-of-school activities

- There was not a simple relationship between science homework and science achievement for Australian students. However, those students who spend some time, but less than four hours a day, on any homework have higher achievement than those who do no homework or four or more hours of homework a day.
- In Australia, 92 per cent of Year 4 students and 96 per cent of Year 8 students have a computer at home. At Year 4, students who used a computer at home and at school had higher science achievement than students who only used a computer in one of these locations. At Year 8, students who used a computer at home and at school or only at home had higher science achievement than students who only used a computer at school.

Students' attitudes and beliefs

- Australian students generally reported quite high levels of self-confidence in science, and while there was no gender difference at Year 4, self-confidence in science was higher for males than females at Year 8. There was a clear positive relationship between level of self-confidence and achievement in science.
- Students' enjoyment of learning science is also related to science achievement. Australia was one of a small number of countries that showed a significant increase from TIMSS-1994/95 at both year levels in the percentage of students who agreed 'a lot' that they enjoy learning science.
- There is no difference between males and females in enjoyment of learning science in Year 4. However, at Year 8, males appear to enjoy learning science more than females.
- Only a third of Australian Year 8 students place a high value on science, almost half that of the international average. In Australia, valuing science is positively related to science achievement.
- Only 40 per cent of Australian Year 8 students expect to finish university compared to the international average of 54 per cent. Students with higher educational aspirations were found to have higher science achievement.

Australian science teachers and their preparation for teaching

- 75 per cent of Year 4 students and 46 per cent of Year 8 students were taught by women, and most teachers were in the 30 – 49 years age group.

- Almost all Year 8 teachers felt prepared to teach all science topics. However, Year 4 teachers were less confident in their readiness to teach topics in physical science and life science than topics in earth science. Most teachers had participated in some form of professional development throughout the year.
- Ten per cent of Year 8 science teachers did not have science as their major area of study.

Classroom activities and characteristics

- In some states, there appear to be factors limiting instruction that are not apparent in other states. In the Northern Territory in particular, there appeared to be problems with children with different academic abilities, the wide range of student backgrounds, uninterested students, low levels of student morale and disruptive students.
- The majority of Year 8 science teachers surveyed agreed with statements reflecting a constructivist way of teaching science, although almost 20 per cent supported the use of learning strategies such as memorisation.
- Around 80 per cent of Australian Year 4 teachers do not use a textbook at all and only eight per cent use a textbook as their primary resource in science, compared to the much greater use of a textbook in other countries. In contrast, most Australian Year 8 science teachers use textbooks and one-third use it as their primary resource for teaching.
- In Australia, very few teachers at either year level have a high emphasis on science homework in comparison with the international average.
- 84 per cent of Australian Year 4 students and 74 per cent of Year 8 students have access to a computer in the classrooms. At Year 4, computers are used to look up ideas and information, which occurs in about half of the lessons in about a quarter of Australian classrooms. However, very few Year 8 science classes use the computer often as part of their lessons.

School contexts for science learning

- Geographic location did not have an effect on science achievement, other than Year 8 students in remote schools scoring at a significantly lower level than students at the same level in metropolitan schools.
- Socioeconomic composition was related to science achievement, with achievement levels significantly higher in schools with low proportions of students from disadvantaged economic backgrounds.
- Student achievement was higher in schools in which principals reported high levels of teacher satisfaction and cohesion, where teachers had high expectations of their students, parents were supportive and involved, and students were engaged and had high expectations of themselves.
- The proportion of Australian Year 4 students reporting a low perception of school safety (that is, a high level of bullying in the school) was the equal third highest of all TIMSS 2002/03 countries. There was a direct relationship between feelings of school safety and science achievement at Year 4 only.
- Achievement was lower in schools where absenteeism, truancy and late arrivals were a problem.

Multilevel analyses of influences on achievement

- At both year levels, language background and ethnicity were amongst the top three strongest influences on science achievement.
- At Year 4, self-confidence in learning science was also a strong influence. Other influences on science achievement are the number of books in the home, the amount of science homework, computer availability, gender, students' perception of safety at school and the number of possessions in the home at the student level and the principals' rating of school and class attendance and the school's level of economic disadvantage at the school/classroom level.
- Other influences on Year 8 achievement are the student's educational aspirations, the number of books in the home, gender, self-confidence in learning science, computer availability, parents' education, valuing science and age at the student level and the school's level of economic disadvantage at the school/classroom level.

Implications for Australian schools and school systems

There are a number of policy considerations arising from these analyses. Science is regarded as one of the foundation areas of learning in the compulsory years of schooling. Studies in other curriculum areas, and many occupations in modern society, require a broad base of scientific literacy, and it is argued that changing societal conditions provide an imperative to broaden and strengthen the base of knowledge and skills in mathematics and science developed through Australia's school systems.

The results from large, comparative international studies such as TIMSS 2002/03 indicate that achievement in science can be improved over a relatively short period of time. The rich database developed for TIMSS 2002/03 can be used to gain further insights into how this might be achieved.

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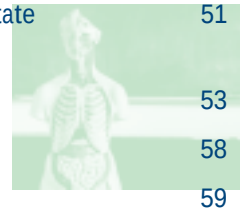

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Chapter 1
Introduction

Chapter 1 Introduction

Towards the end of 2002, just over 10 000 Australian students in Year 4 and Year 8 participated in the Trends in International Mathematics and Science Study[1]. These students completed tests in mathematics and science and answered questionnaires on their background and experiences in learning mathematics and science at school. School principals and the students' mathematics and science teachers also completed detailed questionnaires. In 45 other countries students, teachers and principals completed the same tests and questionnaires.

TIMSS 2002/03 continued Australia's participation in studies devised and managed in conjunction with ACER by the International Association for the Evaluation of Educational Achievement (IEA) in the areas of mathematics and science. The other studies in which Australia participated were the First International Mathematics Study (FIMS), 1964; the First International Science Study (FISS), 1970–1971; the Second International Mathematics Study (SIMS), 1980–1982; and the Second International Science Study (SISS), 1983–1984. The Third International Mathematics and Science Study (TIMSS 1994/95) combined achievement in mathematics and science into a single study, and was partially replicated by TIMSS – Repeat in 1998 and 1999 (which is hereafter referred to as TIMSS 1998/99).

This report provides the Australian perspective for achievement in science in TIMSS 2002/03 – how do our students score, how does this compare internationally and what is happening within Australia? How has achievement changed since 1998/99 and 1994/95, if indeed it has? Has Australia's achievement remained the same in comparison to other countries with which we would normally compare ourselves? Another characteristic of TIMSS is that data are also collected at the teacher and school level, so that such data can be used to highlight characteristics of teaching and learning science in Australia.

Benefits of international studies

Countries differ in the ways their school education is organised, in the curricula they offer, in the preparation they require of their teachers, in the styles the teachers use to present the curricula, 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 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 students; understanding 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 might lie in their own country. IEA studies have become increasingly rigorous in their design and standardisation of their procedures, necessary for making valid inferences from their results.

[1] For comparability across countries and across assessments, testing was conducted at the end of the school year. The countries in the Southern Hemisphere (Australia, Botswana, Chile, Malaysia, New Zealand, Singapore and South Africa) tested in October to December 2002. The remaining countries tested at the end of the 2002-2003 school year: May – June 2003.

Research model for IEA studies

TIMSS has continued the practice begun in the second IEA mathematics study (Robitaille & Garden, 1996) of focusing attention on three levels of the curriculum, all considered in relation to the context in which they occur. These levels and the research questions associated with them are:

- The *intended* curriculum – defined as the curriculum as specified at national or system level. *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?*
- the *implemented* curriculum – defined as the curriculum as interpreted and delivered by classroom teachers. *What opportunities are provided for students to learn mathematics and science? How do instructional practices vary among countries and what factors influence these variations?*
- the *attained* curriculum – which is that part of the curriculum that is learned by students, as demonstrated by their attitudes and achievements. *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?*

The intended curriculum was measured using an international curriculum matching analysis, completed by personnel with expertise in the mathematics and science curriculum areas.

The three aspects of the curriculum bring together three major influences on student achievement. The intended curriculum states society's goals for teaching and learning. These goals reflect the ideals and traditions of the greater society and are constrained by the resources of the education system. The implemented curriculum is what is taught in the classroom. Although presumably inspired by the intended curriculum, actual classroom events are usually determined in large part by the teacher, whose behaviour may be greatly influenced by his or her education, training, and experience, by the nature and organisational structure of the school, by interaction with teaching colleagues, and by the composition of the student body. The attained curriculum is what the students actually learn. Student achievement depends partly on the implemented curriculum and its social and educational context, and to a large extent on the characteristics of individual students, including ability, attitude, interests, and effort.

Data on the implemented curriculum were collected as part of the TIMSS 2002/03 survey of student achievement. Questionnaires completed by the mathematics and science teachers of the students in the survey, and by the principals of their schools, provided information about the topics in mathematics and science that were taught, the instructional methods used in the classroom, the organisational structures that supported teaching, and the factors that were seen to facilitate or inhibit teaching and learning. The student achievement survey provided data for the study of the attained curriculum. The wide-ranging mathematics and science tests that were administered to nationally representative samples of students provided not only a sound basis for international comparisons of student achievement, but a rich resource for the study of the attained curriculum in each country. Information about students' characteristics, and about their attitudes, beliefs, and experiences, was collected from each participating student. This information was used to identify the student characteristics associated with learning and provide a context for the study of the attained curriculum.

Design and administration of TIMSS

Organisation

TIMSS was organised by the IEA and managed by the International Study Centre, Lynch School of Education, at Boston College in the United States of America. The IEA Data Processing Centre (DPC) in Hamburg, Germany, was responsible for checking and processing data and for constructing the international database. The IEA Secretariat in Amsterdam, the Netherlands, coordinated all translations and adaptations and organised the international quality control monitors. Statistics Canada, based in Ottawa, Canada, advised NRCs on their sampling plans, monitored sampling progress, and calculated the sampling weights. Educational Testing Service (ETS) in New Jersey, USA, conducted psychometric analysis of the field-

(4)(8) Armenia	(4)(8) Iran, Islamic Republic of	(8) Palestinian National Authority
(4)(8) Australia	(8) Israel	(4)(8) Philippines
(8) Bahrain	(4)(8) Italy	(8) Romania
(4)(8) Belgium (Flemish)	(4)(8) Japan	(4)(8) Russian Federation
(8) Botswana	(8) Jordan	(8) Saudi Arabia
(8) Bulgaria	(8) Korea, Republic of	(4)(8) Scotland
(8) Chile	(4)(8) Latvia	(8) Serbia & Montenegro
(4)(8) Chinese Taipei	(8) Lebanon	(4)(8) Singapore
(4)(8) Cyprus	(4)(8) Lithuania	(8) Slovak Republic
(8) Egypt	(8) Macedonia, Republic of	(4)(8) Slovenia
(4)(8) England	(8) Malaysia	(8) South Africa
(8) Estonia	(4)(8) Moldova	(8) Sweden
(8) Ghana	(4)(8) Morocco	(4)(8) Tunisia
(4)(8) Hong Kong SAR	(4)(8) Netherlands	(4)(8) United States of America
(4)(8) Hungary	(4)(8) New Zealand	
(8) Indonesia	(4)(8) Norway	

Benchmarking participants

(8) Basque Country, Spain
(4)(8) Indiana State, United States of America
(4)(8) Ontario Province, Canada
(4)(8) Quebec Province, Canada

Legend

(4) Year 4
(8) Year 8

Figure 1.1 Participants in TIMSS 2002/03

test data and scaled the achievement data from the main data collection. In Australia, the study was funded by the Australian Government Department of Education, Science and Training (DEST) and by State and Territory Departments of Education in proportion to the size of their student population. The study was managed in Australia by the Australian Council for Educational Research (ACER), which represents Australia on the IEA.

International participation in TIMSS

Testing for TIMSS 2002/03 was carried out in 46 countries. Two provinces of Canada, one state of the United States of America[2] and Basque Country, Spain, were also in the study as benchmarking[3] participants. The countries and regions and the year levels at which they participated are shown in Figure 1.1.

The Australian sample of schools and students

There are differences in the samples of students that have an impact on comparability of results across TIMSS cycles. For TIMSS 1994/95, students were selected from the two adjacent year levels containing the largest number of nine year olds (defined as Population 1) and 13 year olds (defined as Population 2). School entry age is not standard in Australia, nor is the year level into which students start school or move from primary schooling to secondary schooling, which meant that a range of years had to be selected from which to sample students. Due to these differences, data collection for TIMSS 1994/95 was undertaken at the following year levels:

- Years 3 and 4 and Years 7 and 8 in the Australian Capital Territory, New South Wales, Victoria and Tasmania; and
- Years 4 and 5 and Years 8 and 9 in Queensland, South Australia, Western Australia and the Northern Territory.

The target population for TIMSS 1998/99 was defined as the upper of the two adjacent years identified in TIMSS 1994/95 as Population 2. In Australia, this was interpreted as Year 8 in the Australian Capital Territory, New South Wales, Victoria and Tasmania, and Year 9 in Queensland, South Australia, Western Australia and the Northern Territory, and students were sampled from these year levels. Population 1 was not sampled internationally in TIMSS 1998/99.

For the TIMSS 2002/03 and subsequent cycles, a decision was made by the IEA and the International Study Centre that the focus for Population 1

[2] In addition to the United States of America as a whole, one state (Indiana) was included as an entity.

[3] Benchmarking participants: Provinces or regions that participated in TIMSS for their own internal benchmarking. Data from these provinces are not included in the international average and are not included in the national reports.

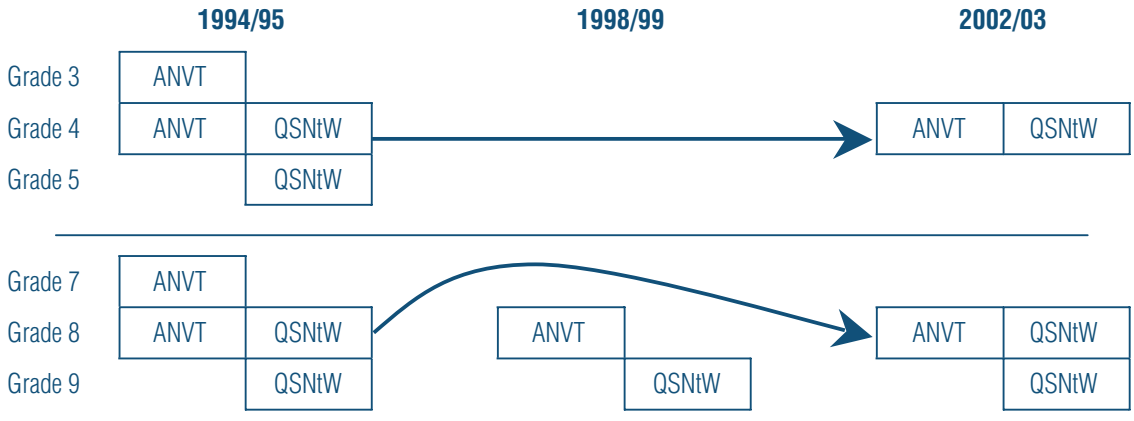
would be Year 4 and for Population 2 Year 8, as these were in most cases the upper of the two adjacent year levels containing the most 9 or 13 year olds. The implication of this decision for Australia is that simple trend comparisons cannot be made between TIMSS 2002/03 and TIMSS 1998/99, as the populations are different. Internationally, however, this is not the case, and a number of countries are able to make comparisons between each of the TIMSS cycles for Population 2. However, comparisons can be made with TIMSS 1994/95, using data sets containing only the revised target years from each state and territory.

Figure 1.2 shows the structure of the three TIMSS data sets. An extra sample of Year 9 students was taken in 2002/03 in the four states of Australia in which this was the year level sampled in TIMSS 1998/99. In a follow-up report to this, data for Year 8 in the Australian Capital Territory, New South Wales, Victoria and Tasmania and Year 9 in Queensland, South Australia, Northern Territory and Western Australia for TIMSS 2002/03 will be combined.

By combining Year 8 students in New South Wales, Victoria, Tasmania and the Australian Capital Territory, and Year 9 students in Queensland, South Australia, Western Australia and the Northern Territory, for TIMSS 1994/95 and TIMSS 2002/03, we will create data sets with year levels that match those of TIMSS 1998/99. In this way we will be able to examine changes in achievement and contextual factors in mathematics and science over the eight-year span from 1994 to 2002.

Table 1.1 shows the effect that the structural differences in Australian state and territory[4] education systems have on the ages of students in the target populations. The youngest students were those in Queensland and Western Australia, which were the only states that, at the time when these cohorts were entering school, enrolled students directly into Year 1. All other states had some form of preparatory school year. The main conclusion that can be drawn from this table is that students in Queensland and Western Australia may have had up to a year less schooling than their counterparts in the rest of Australia at the time of testing. On average there is about eight months difference in the ages of Year 4 or Year 8 students in Queensland and Western Australia compared to their respective cohort in other states.

The international sample design for TIMSS is generally referred to as a two-stage stratified cluster sample design. The first stage consists of a sample of schools, which in Australia is stratified by state and by sector; the second stage consists of a sample of one classroom from the target year in each sampled school. To ensure unbiased data, the International Study Center set minimum participation rates of 85 per cent of sampled schools and 85 per cent of sampled students (or a combined schools and students participation rate of 75%). Non-participating sampled schools could



Legend
A=Australian Capital Territory, N=New South Wales, V=Victoria, T=Tasmania, Q=Queensland, S=South Australia, Nt=Northern Territory, W=Western Australia

Figure 1.2 Structure of the Australian samples for each of the three TIMSS studies

[4] For the remainder of this report, the Australian states and territories will be collectively referred to as the 'states'.

Table 1.1 School starting and school entry grades and ages of TIMSS students, by state

State	First year of full-time school	TIMSS 2002/03 Population 1		First year of secondary school	TIMSS 2002/03 Population 2	
		Age range	Average age		Age range	Average age
NSW	Kindergarten	9.0 – 11.7	10.0	Year 7	12.2 – 15.5	14.0
VIC	Preparatory	8.8 – 11.2	10.1	Year 7	13.1 – 16.1	14.1
QLD	Year 1	8.8 – 11.0	9.4	Year 8	11.8 – 15.8	13.4
SA	Reception	8.5 – 11.8	9.9	Year 8	12.8 – 15.2	13.8
WA	Year 1	8.2 – 11.0	9.4	Year 8	12.5 – 14.9	13.4
TAS	Preparatory	9.0 – 11.3	10.2	Year 7	12.9 – 15.6	14.2
NT	Transition	8.9 – 10.9	9.8	Year 8	12.9 – 15.5	13.8
ACT	Kindergarten	9.1 – 11.8	10.1	Year 7	13.0 – 15.2	14.1

be replaced by replacement schools that had been matched according to strata and size.

However, countries that only achieved these requirements by the use of replacement schools are annotated in the International Reports. Countries with less than 50 per cent of sampled schools participating are segregated in the International Reports. Australia achieved the required participation rate for Population 2. However, the participation rate for Population 1 fell just under the requirement, resulting in an annotation in the International Reports[5]. Despite this annotation, the sample is believed to be representative and sufficient for the reporting and analysis that follows. Sampling weights were calculated by Statistics Canada to ensure that the population at each year level was appropriately represented by the students participating in TIMSS. The weighted numbers for Australia for Population 1 and Population 2, along with the number of schools and actual number of students participating are shown in Table 1.2.

How is science assessed in TIMSS?

The science assessment for TIMSS 2002/03 is framed by two organising dimensions, a content dimension and a cognitive dimension (Mullis, Martin, Smith, Garden, Gonzalez, Chrostowski and O'Connor, 2003). There are five content domains: life science, chemistry, physics, earth science, and environmental science, and three cognitive domains: factual knowledge, conceptual understanding, and reasoning and analysis. At Year 8 level, each content domain is a separate reporting category. At Year 4 level, only three reporting categories are included (life science, physical science, and earth science), with physics and chemistry combined into physical science. In contrast to TIMSS 1998/99, where a separate reporting category of "Scientific Inquiry and the Nature of Science" was included, the TIMSS 2002/03 framework treats scientific inquiry as a separate assessment strand that overlaps all of the fields of science and has both content- and skills-based components. Although scientific inquiry is

Table 1.2 Australia's designed and achieved sample in TIMSS 2002/03, by state

State	Designed school sample	Population 1				Designed school sample	Population 2			
		N Schools	N students	Weighted N	Weighted %		N Schools	N students	Weighted N	Weighted %
NSW	40	35	912	90781	35.3	40	34	880	84456	32.8
VIC	35	32	675	62852	24.4	35	34	860	65435	25.4
QLD	35	31	759	43597	16.9	35	33	881	48270	18.8
SA	30	27	600	20901	8.1	30	28	703	18902	7.3
WA	30	27	661	26123	10.2	30	26	702	27616	10.7
TAS	30	25	501	6444	2.5	30	26	625	6424	2.5
NT	15	13	251	2300	.9	15	14	321	1578	.6
ACT	15	14	316	4224	1.6	15	15	383	4727	1.8
Total	230	204	4675	257222	100.0	230	210	5355	257408	100.0

[5] The combined schools and students participation rate for Population 1 was 73% and over 75% for Population 2.

not treated as a separate reporting category in TIMSS 2002/03, the framework specifies that outcomes related to scientific inquiry will represent up to 15 per cent of the total science assessment time at each year level to permit some level of reporting student performance in this area. The two dimensions and their domains are the foundation of the science assessment. The content domains define the specific science subject matter covered by the assessment, and the cognitive domains define the sets of behaviours expected of students as they engage with the science content.

Content domains

For each of the five science content domains, the framework identifies several main topic areas to be included in the assessment. These are shown in Table 1.3. Most of the main topics are appropriate for both year levels, but some topics are included at Year 8 only. For each main topic area, the frameworks document includes a list of specific subtopics or assessment objectives appropriate for each year level. This structure of the frameworks highlights the development of knowledge and abilities across the years. For example, physics is further categorised by

- *Physical states and changes in matter,*
- *Energy types, sources and conversions,*

Table 1.3 TIMSS science content domains and proportion of assessment for each domain

Science content domains	Topics	Target percentages of TIMSS assessment devoted to content domains	
		Year 4	Year 8
Life Science	Types, characteristics and classification of living things Structure, function and life processes in organisms Cells and their functions (Year 8 only) Development and life cycles of organisms Reproduction and heredity Diversity, adaptation and natural selection Ecosystems Human health	45	30
Physical Science		35	*
Chemistry	Classification and composition of matter Particulate structure of matter (Year 8 only) Properties and uses of water Acids and bases (Year 8 only) Chemical change	*	15
Physics	Physical states and changes in matter Energy types, sources and conversions Heat and temperature Light Sound and vibration (Year 8 only) Electricity and magnetism Forces and motion	*	25
Earth Science	Earth's structure and physical features Earth's processes, cycles and history Earth in the solar system and the universe	20	15
Environmental Science	Changes in population (Year 8 only) Use and conservation of natural resources Changes in environments	*	15

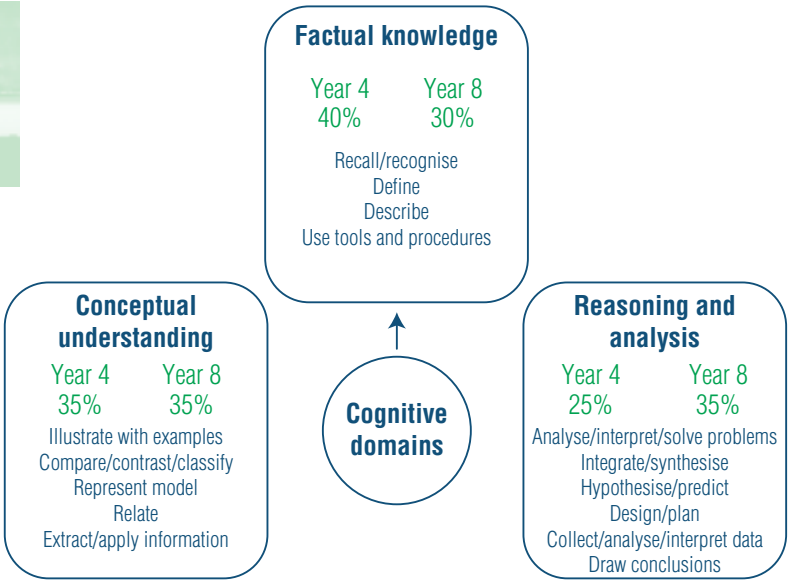


Figure 1.3 TIMSS science cognitive domains and proportion of assessment for each domain

- *Heat and temperature,*
- *Light,*
- *Sound and vibration,*
- *Electricity and magnetism,*
- *Forces and motion.*

Each topic area is presented as a list of objectives covered in the curriculum of a majority of participating countries, at either Year 4 or Year 8. The organisation of topics across the content domains reflects some minor revision from the reporting categories used in the 1994/95 and 1998/99 assessments. However, each of the trend items[6] from TIMSS 1994/95 and TIMSS 1998/99 may be mapped directly into the content domains defined for TIMSS 2002/03.

Cognitive domains

The set of skills and abilities to be demonstrated by students in responding to items across the science topics is organised into the three broad cognitive domains specified in the framework – factual knowledge, conceptual understanding, and reasoning and analysis (see Figure 1.3). A brief description of each cognitive domain and the set of skills and abilities required by TIMSS items corresponding to each are listed below.

Factual knowledge: This refers to students' knowledge base of relevant science facts, information, tools, and procedures. Items may require students to recall/recognise accurate statements about science facts and concepts; demonstrate knowledge/use of correct scientific terms; describe scientific processes, properties, characteristics, structure, function, and relationships; and demonstrate knowledge about the use of scientific tools and procedures.

Conceptual understanding: Students should be able to demonstrate an understanding of the relationships that explain the physical world and relate the observable to more abstract or general concepts. Items may require students to provide examples to illustrate general concepts; compare/contrast and classify objects, materials and organisms; use diagrams/models; relate underlying concepts to observed or inferred properties/behaviours; extract/apply textual, tabular or graphical information; find solutions to problems involving the direct application of concepts; and provide explanations.

Reasoning and analysis: This includes problem-solving and scientific reasoning processes involved in the more complex tasks related to science. Items may require students to analyse/interpret problems; integrate/synthesise a number of factors or related concepts across mathematics and science; hypothesise/predict; design investigations and procedures; analyse/interpret data; draw conclusions; generalise; evaluate; and justify explanations and problem solutions. Examples of the behaviours associated with each of the cognitive domains can be found in Mullis et al. (2003).

[6] Trend items are items which are repeated in two or more cycles of assessment.

Scientific inquiry

The scientific inquiry strand is assessed through longer problem-solving and inquiry tasks as well as some individual items that require students to apply scientific inquiry skills in a practical context. While not full scientific investigations, the tasks are designed to require a basic understanding of the nature of science and investigation and elicit some of the skills essential to the scientific inquiry process. Tasks may include some portion of the following major phases in the scientific inquiry process:

- Formulating questions and hypotheses
- Designing investigations
- Collecting, representing, analysing, and interpreting data
- Drawing conclusions and developing explanations based on evidence.

The same general assessment outcomes related to scientific inquiry are appropriate for both Year 4 and Year 8, but the specific understandings and abilities to be demonstrated increase in complexity at the higher year level. The items and tasks developed to measure scientific inquiry skills are set in content-based contexts. These items are, therefore, classified with respect to content and cognitive categories as well as scientific inquiry and contribute to the appropriate content reporting scale.

Test design and administration

The development of the mathematics and science tests used in TIMSS 2002/03 was a collaborative process. The curriculum guides and textbooks of many countries were analysed to identify priority and common topics, and curriculum specialists collaborated to produce an international framework for each of mathematics and science which guided the test development. Test items submitted by many countries were reviewed by mathematics and science specialists, and by testing specialists, and were examined for possible gender, racial or cultural bias, before they were field-tested.

The focus of TIMSS is on curriculum-based learning, and for greater resemblance to classroom activities, about one-third of the TIMSS testing time was devoted to items requiring students to construct their answers. Most of these required only short answers, some just a word or a number, but more often a sentence or phrase or diagram. In some cases students had to write down a complete explanation or show some extended, detailed working.

The inclusion of open-ended questions in TIMSS meant that scoring guides had to be developed that would be able to be applied reliably in all countries. TIMSS also used a two-digit coding scheme for all items that required a short or extended answer. The first digit registered the degree of correctness of the students' answer. For short-answer items, the first digit was 1 (correct) or 7 (incorrect). The second digit was used to code the type of correct or incorrect response given. These codes provide a rich source of information for further research on students' problem solving strategies, thought processes and misconceptions.

A large number of test items were required to cover the range of topics and abilities, at both Year 4 and Year 8. For each year level, mathematics and science items were grouped into clusters, which were then rotated through 12 booklets, with each cluster found in more than one booklet. The booklets were designed to be administered in two sessions, separated by a short break. Each session was of 45 minutes duration at Year 8 and 36 minutes at Year 4. Each booklet contained both mathematics and science items, and included multiple choice, short answer and extended response items. Participating students completed only one of these booklets, which were evenly distributed within classes. This meant that only two or three students in each class completed the same booklet.

Procedures for administering the test were determined by the TIMSS International Study Centre so that data from all students from all schools in all countries could be considered equivalent. These were operationalised by National Centres in each country, such as the ACER in Australia. School Coordinators, nominated by the school principal, assisted the National Centre with the management of TIMSS within the school, including administering the school and teacher questionnaires. The actual test and student questionnaires were administered, in most cases, by a teacher from the school. The Test Administrator followed strict guidelines and had to complete a report about any situation that constituted a deviation from these guidelines. A National Quality Control Observer visited 10 per cent of schools to observe the test administration. An International Quality Control Observer visited a further 15 schools as well as examining the operations of the National Centre.

TIMSS contextual framework

It is very important in a study such as TIMSS that student achievement is not considered in isolation from the economic, social, cultural and educational contexts in which achievement occurs. To ensure that these data were available, TIMSS included four background questionnaires. The development of these questionnaires was also a collaborative process, and was 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. Briefly:

- the School Questionnaire sought information about school characteristics (location, size, year levels catered for etc), resources, time for planning, and curriculum offerings;
- the Teacher Questionnaires asked about teacher qualifications and preparation, how teachers organise and carry out instruction in mathematics and science, pedagogical practices, teaching styles, and views on current issues in mathematics and science education;
- the Student Questionnaire collected demographic information, data on how students spend their time both in and out of school, and their attitudes towards mathematics and science.

As well, a questionnaire was developed that the NRC completed which gathered information about major organisational factors at the system level, such as age of starting school, division between primary and secondary school, teacher certification requirements, and curriculum documentation.

In primary schools, the class teacher of the sampled class was asked to complete a combined mathematics and science questionnaire, unless they specified that science was taught by another teacher. In secondary schools, the mathematics teacher of the sampled class completed the Mathematics Teacher Questionnaire, and all teachers who taught science to that class were asked to complete a Science Teacher Questionnaire.

Organisation of this report

Chapters 2 and 3 of this report focus on the achievements of Australia's Year 4 and Year 8 students in science. Chapter 2 places Australian students in an international context and allows educators to review Australian students' results in comparison with other countries. Chapter 2 also describes the international benchmarks, and shows Australian students' performance in comparison with the other TIMSS countries. Chapter 3 focuses on results for Australian states and examines achievement in the individual TIMSS content areas. Chapter 4 examines the Australian TIMSS students in detail, including their attitudes and beliefs about science, and relationships between these variables and student achievement. Results for males and females, Indigenous students, and those with a language background other than English are included in this section. Chapter 5 profiles the TIMSS teachers and schools and examines achievement in relation to teachers' and principals' perception of the school and class environment, and school size and geographic location. TIMSS sampling methodology is such that intact mathematics classrooms are taken as the sampling unit, and as in some cases this is also the science class, particularly for Year 4 students, we are able to examine some class-level as well as school-level issues and relate them to student achievement.

Multilevel analyses of school, class and student factors related to achievement are presented in Chapter 5, and Chapter 6, the final chapter, presents a summary and policy considerations, arising from the TIMSS results.

Chapter 2
Australia's science results in an international context

Chapter 2
Australia's science results in an international context

In this chapter, the international TIMSS results in science are shown in terms of averages and distribution of achievement for all of the participating countries, presented and discussed from an Australian perspective. Gender differences are also shown and the International Benchmarks are defined and explicated, with Australia's level of performance at each of the benchmarks shown along with that of some similar countries and trading partners. Results are included for both Year 4 and Year 8 in this chapter.

Interpreting between-country similarities and differences

When interpreting the comparative results presented in this chapter and others, it is important to remember that each country's result is an estimate of the total population value, inferred from the result obtained by the sample of students tested. Because it is an estimate, it is subject to some potential level of error. An idea of the variability of the average scores is given by the standard error of the average (se) presented in the tables with the average score. We can say with 95% confidence that the true population average lies within about two standard errors (1.96, to be precise) each side of the sample average, and as a guide, a country's result is not different from another country's result if these confidence intervals overlap. Standard errors are influenced by the size and design of the sample and the variation in the sample.

To illustrate the use of standard errors with the average to evaluate difference, we could ask the question: *Does Australia's Year 4 achievement level in science differ from the international average?* From Table 2.1, Australia's average score is 521 with a standard error of 4.2, while the international average is 489 with a standard error of 0.9. The population average for Australia therefore lies somewhere between 512.6 and 529.4 *(the confidence interval),* while the international average lies between 487.2 and 490.8. As these intervals do not overlap, we can say that the averages are statistically different. We could also ask: *Is Australia's achievement level in science significantly higher than that of New Zealand?* The confidence interval for Australia is 512.6–529.4, while that for New Zealand is 515.0–525.0. As the confidence intervals overlap, we can say (with 95% confidence) that Australia's average is not significantly higher than that of New Zealand.[1]

To assist identifying where Australia stands in an international context, we have annotated each table (in the column headed '2002/03') as follows:

- Countries that are shaded at the top of the table and are annotated with a ▲ are countries whose students achieved significantly higher scores than Australian students;
- Australian students performed at similar levels to those students in countries annotated with a •;
- Australian students performed significantly better than students in countries shaded at the bottom of the table that are annotated with a ▼.

This notation (but not the shading) has been used in the column headed '1994/95' to provide a comparison of Australia's performance with that in TIMSS 1994/95 (upper year). Countries that did not participate in TIMSS 1994/95 are noted with a dash.

[1] When comparing many countries at one time, a statistical adjustment must be made so that the probability level remains at 0.05. This is referred to as 'adjusting for multiple comparisons'.

Twenty-five countries or education systems took part in the testing at Year 4 level, and 46 countries or education systems at Year 8 level. Table 2.1 presents the average science scores for all of the countries that participated in TIMSS 2002/03 relative to the average for Australian students for Year 4, and Table 2.2 presents the same data for Year 8.

Also shown in Table 2.1 and Table 2.2 is the average age of students in the year level and a measure of the level of development of the country – the United Nations Development Program's human development index (HDI). This index is a summary measure of human development in a country over three basic dimensions: life expectancy at birth, knowledge – measured by adult literacy rate and combined primary, secondary and tertiary gross enrolment ratio, and GDP per capita. Australia's HDI is 0.939, which is the highest of any country in the Year 4 group and second only to the Scandinavian countries in the Year 8 group of countries.

Both of these items should be taken into account when examining differences between countries' performance. For example the students in Korea scored significantly better in the science tests at Year 8 than students from Australia, and yet their level of human development, measured by the HDI, is 0.879, compared to Australia's 0.939. However the average age of Korean students in TIMSS 2002/03 was 14.6 years, a little more than eight months older than Australian students sitting the same test.

Some notes about sampling

Readers will notice several footnotes about sampling on the international comparative achievement charts. These footnotes indicate where there is some concern about the sampling, and that this should be borne in mind when interpreting the results. For example, Korea, while testing the same cohort of students as other countries, did so at the beginning of the 2003 school year, rather than at the end of the year. Several countries did not completely meet the sample requirements. As noted in Chapter 1, these were specified as 85 per cent of originally sampled schools, without replacement, and 85 per cent of students within the schools, or a combined rate of 75 per cent. Testing in the southern hemisphere countries was done late in the school year, and although, in Australia, sufficient schools initially agreed to participate in TIMSS, when faced with the reality of scheduling testing along with reports, camps, concerts and other end of year activities, some schools changed their minds. While project staff were in many cases able to enlist the sampled schools, Australia did not quite achieve this for the Year 4 sample, and so Australia's results are annotated as 'met guidelines for sample participation only after replacement schools were included'. Given that the replacement schools were selected by Statistics Canada at the same time as the main study schools, this should not mean that Australia's results are any less valid.

Other countries had more difficulty than Australia in reaching the sample participation rates without the use of replacement schools. These are also annotated in the tables. In many countries participation in studies such as TIMSS is highly regarded, and in other countries testing is conducted by the Ministry of Education and for these countries sampling is generally not an issue.

In the International Reports, the achievement level of England is 'below the line' at Year 8 level as it did not meet the minimum sample participation rates. Whilst for the purposes of this report the results for England are included in the main body of the table, it is purely for a general comparison with our own results.

How did Australia perform internationally?

Science - Year 4

The average age of students in Year 4 varied by a full year between countries – from around 11 years in Latvia, Moldova, Lithuania, Armenia and Morocco, to under 10 years in Cyprus, Italy, Australia, Scotland, Slovenia and Norway. Years of schooling was most commonly 4 years, but ranged from 3 years in the Russian Federation and Slovenia through to 5.5 years in New Zealand.

At Year 4, Singapore outperformed all other countries, and Chinese Taipei outperformed all countries other than Singapore[2] (Table 2.1). Australian Year 4 students' achievement in science was significantly higher than the international average, and was not significantly different to that of Hungary, the Russian Federation, the Netherlands, New Zealand, Belgium (Flemish), Italy and Lithuania.

[2] The multiple comparison tables for the international results are included in Appendix 1.

Table 2.1 Distribution of science achievement at Year 4

All Year 4 TIMSS 2002/03 countries	Average scale score (se)	2002/03	1994/95	Average age	Years of schooling	Human Development Index*
Singapore	565 (5.5)	▲	•	10.3	4	0.884
Chinese Taipei	551 (1.7)	▲	-	10.2	4	–
Japan	543 (1.5)	▲	▲	10.4	4	0.932
†Hong Kong SAR	542 (3.1)	▲	▼	10.2	4	0.889
†England	540 (3.6)	▲	•	10.3	5	0.930
†United States of America	536 (2.5)	▲	•	10.2	4	0.937
Latvia	532 (2.5)	▲	▼	11.1	4	0.811
Hungary	530 (3.0)	•	▼	10.5	4	0.837
Russian Federation	526 (5.2)	•	-	10.6	3 or 4	0.779
†Netherlands	525 (2.0)	•	•	10.2	4	0.938
†Australia	521 (4.2)			9.9	4 or 5	0.939
New Zealand	520 (2.5)	•	▼	10.0	4.5 – 5.5	0.917
Belgium (Flemish)	518 (1. 8)	•	-	10.0	4	0.937
Italy	516 (3.8)	•	-	9.8	4	0.916
1Lithuania	512 (2.6)	•	-	10.9	4	0.824
†Scotland	502 (2.9)	▼	▼	9.7	5	0.930
Moldova, Rep. of	496 (4.6)	▼	-	11.0	4	0.700
Slovenia	490 (2.5)	▼	-	9.8	3 or 4	0.881
International average	**489 (0.9)**			**10.3**	**4**	**–**
Cyprus	480 (2.4)	▼	▼	9.9	4	0.891
Norway	466 (2.6)	▼	▼	9.8	4	0.944
Armenia	437 (4.3)	▼	-	10.9	4	0.729
Iran, Islamic Rep. of	414 (4.1)	▼	▼	10.4	4	0.719
Philippines	332 (9.4)	▼	-	10.8	4	0.751
Tunisia	314 (5.7)	▼	-	10.4	4	0.740
Morocco	304 (6.7)	▼	-	11.0	4	0.606

* Taken from United Nations Development Program's Human Development Report 2003, p237–240
† Met guidelines for sample participation rates only after replacement schools were included
1 National Desired Population does not cover all of International Desired Population
( ) Standard errors appear in parentheses
- Did not participate in TIMSS 1994/95 at this Year level
▲ score statistically higher than Australia's
• score statistically no different than Australia's
▼ score statistically lower than Australia's

Australia's performance was significantly lower than that of seven other countries: Singapore, Chinese Taipei, Japan, Hong Kong SAR, England, the United States of America, and Latvia, and significantly higher than that of 10 other countries, including Scotland and the Philippines.

Australia's achievement in Year 4 science has remained statistically the same since TIMSS 1994/95, as has that of the United States of America. In contrast, a number of other countries participating in the Year 4 assessment showed significant improvement over this period of time: Singapore by 42 score points, Hong Kong SAR by 35 score points and Latvia by 43 score points. New Zealand students' average score also increased by 18 score points over this time. It is difficult to make a direct comparison with TIMSS 1994/95 in terms of the relative position of Australia internationally because there are different countries in each assessment. However, of the countries that participated in both TIMSS 1994/95 and 2002/03, almost half have an average score in 2002/03 that is significantly higher than Australia's, compared to only one country in 1994/95.

Science – Year 8

The oldest students in the Population 2 sample were more than 15 years old – from 15.5 years in Ghana to 15.2 in Morocco and Estonia, 15.1 in South Africa and Botswana, and 15 in Latvia and Romania. With an average age of 13.9 years, Australian students were amongst the youngest in the sample. Other countries with students under

Table 2.2 Distribution of science achievement at Year 8

All Year 8 TIMSS 2002/03 countries	Average scale score (se)	2002/03	1994/95	Average age	Years of schooling	Human development Index*
Singapore	578 (4.3)	▲	▲	14.3	8	0.884
Chinese Taipei	571 (3.5)	▲	-	14.2	8	–
⋈Korea, Rep. of	558 (1.6)	▲	▲	14.6	8	0.879
†Hong Kong SAR	556 (3.0)	▲	▼	14.4	8	0.889
Estonia	552 (2.5)	▲	-	15.2	8	0.833
Japan	552 (1.7)	▲	▲	14.4	8	0.932
‡England	544 (4.1)	▲	•	14.3	9	0.930
Hungary	543 (2.8)	▲	•	14.5	8	0.837
†Netherlands	536 (3.1)	•	•	14.3	8	0.938
‡United States of America	527 (3.1)	•	•	14.2	8	0.937
Australia	527 (3.8)			13.9	8 or 9	0.939
Sweden	524 (2.7)	•	•	14.9	8	0.941
Slovenia	520 (1.8)	•	•	13.8	7 or 8	0.881
New Zealand	520 (5.0)	•	▼	14.1	8.5 – 9.5	0.917
1Lithuania	519 (2.1)	•	▼	14.9	8	0.824
Slovak Republic	517 (3.2)	▼	-	14.3	8	0.836
Belgium (Flemish)	516 (2.5)	▼	•	14.1	8	0.937
Russian Federation	514 (3.7)	▼	•	14.2	7 or 8	0.779
Latvia	512 (2.6)	▼	▼	15.0	8	0.811
†Scotland	512 (3.4)	▼	▼	13.7	9	0.930
Malaysia	510 (3.7)	▼	-	14.3	8	0.790
Norway	494 (2.2)	▼	▼	13.8	7	0.944
Italy	491 (3.1)	▼	-	13.9	8	0.916
2Israel	488 (3.1)	▼	▼	14.0	8	0.905
Bulgaria	479 (5.2)	▼	•	14.9	8	0.795
Jordan	475 (3.8)	▼	-	13.9	8	0.743
International average	**474 (0.6)**	▼		**14.5**	**8**	**–**
Moldova, Rep. of	472 (3.4)	▼	-	14.9	8	0.700
Romania	470 (4.9)	▼	▼	15.0	8	0.773
1Serbia and Montenegro	468 (2.5)	▼	-	14.9	8	–
Armenia	461 (3.5)	▼	-	14.9	8	0.729
Iran, Islamic Rep. of	453 (2.3)	▼	▼	14.4	8	0.719
1Macedonia, Rep. of	449 (3.6)	▼	-	14.6	8	0.784
Cyprus	441 (2.0)	▼	▼	13.8	8	0.891
Bahrain	438 (1.8)	▼	-	14.1	8	0.839
Palestinian Nat'l Auth.	435 (3.2)	▼	-	14.1	8	0.731
Egypt	421 (3.9)	▼	-	14.4	8	0.648
1Indonesia	420 (4.1)	▼	-	14.5	8	0.682
Chile	413 (2.9)	▼	-	14.2	8	0.831
Tunisia	404 (2.1)	▼	-	14.8	8	0.740
Saudi Arabia	398 (4.0)	▼	-	14.1	8	0.769
1‡Morocco	396 (2.5)	▼	-	15.2	8	0.606
Lebanon	393 (4.3)	▼	-	14.6	8	0.752
Philippines	377 (5.8)	▼	-	14.8	8	0.751
Botswana	365 (2.8)	▼	-	15.1	8	0.614
Ghana	255 (5.9)	▼	-	15.5	8	0.567
South Africa	244 (6.7)	▼	▼	15.1	8	0.684

* Taken from United Nations Development Program's Human Development Report 2003, p237–240
⋈ Korea tested the same cohort of students as other countries, but later in 2003, at the beginning of the next school year
† Met guidelines for sample participation rates only after replacement schools were included
‡ Nearly satisfied guidelines for sample participation rates only after replacement schools were included
‡ Did not satisfy guidelines for sample participation rates
1 National Desired Population does not cover all of International Desired Population
2 National Desired Population covers less than 90% of National Desired Population
( ) Standard errors appear in parentheses
- Did not participate in TIMSS 1994/95 at this Year level
▲ score statistically higher than Australia's
• score statistically no different than Australia's
▼ score statistically lower than Australia's

14 were Scotland, Slovenia, Italy, Norway, Cyprus and Jordan. While there is clearly a wide variety in age, most students had had 8 years of formal schooling. However, years of schooling ranged from seven years in Norway to 9.5 in New Zealand.

Table 2.2 provides the international achievement data for Year 8 students. At Year 8, as at Year 4, the achievement levels of students in Singapore and Chinese Taipei were significantly higher than that of students in any other country, around 100 score points higher than the international average. As well as these two countries, Korea, Hong Kong SAR, Japan and England were among the countries whose achievement scores were significantly higher than those of Australian students. Australia was one of 23 countries that scored significantly higher than the international average, and our performance was statistically similar to that of the Netherlands, the United States of America, Sweden, Slovenia, New Zealand and Lithuania. Australia's achievement level was significantly higher than that of 21 other countries, including Scotland, Malaysia, Indonesia and the Philippines.

Australian Year 8 students' achievement level in science increased significantly from TIMSS 1994/95, by approximately 13 score points. Students in the United States of America also increased their average scale score by 15 score points, New Zealand students by nine score points and Hong Kong SAR by a massive 46 score points. As a result, some countries that were equal to Australia in TIMSS 1994/95 are now statistically below Australia. Three countries have now joined the three, who, in TIMSS 1994/95, had significantly higher average scores than Australia, although of these three countries, only Hong Kong SAR participated in 1994/95.

Gender differences in science achievement

The average science achievement scores for all participating countries, separately for male and female students, are shown in Figure 2.1 for Year 4 and Figure 2.2 for Year 8.

In the figures, gender differences are shown by a horizontal bar for each country, illustrating the amount of 'difference' between the average achievement scores of males and females in that country. Of course, many 'differences' are simply an artefact of sampling and measurement error. If a difference is large enough to be statistically significant, the horizontal bar is shaded rather than outlined.

The analysis of achievement by gender presents some very interesting differences between countries. Some of the gender differences in science in TIMSS 1994/95 were very large, and all were in favour of males. In Australia, at the upper year level of Population 1 (Year 4) males performed significantly better than females but there was no significant gender differences at Population 2 (Year 8). Overall, almost all of the gender differences in science, and certainly all of the *significant* gender differences in TIMSS 1994/95 internationally at both Year 4 and Year 8 level, were in favour of males.

In TIMSS 2002/03, however, gender differences were *not* consistently in favour of males. At Year 4 males scored significantly higher than females in Scotland, the Netherlands, Cyprus, Chinese Taipei and the United States of America, but females scored significantly higher than males in Armenia, Moldova, the Philippines and Iran. The significant differences ranged in size from five score points in the United States of America to 20 score points in Iran, and all of the larger gender differences were in favour of females.

At Year 8 the more traditional gender pattern in science was evident with 29 out of the 46 countries with significant gender differences in favour of males. In seven countries females scored higher than males. In Macedonia and Moldova the differences were in the region of eight score points in favour of females, however in the Middle Eastern countries of Armenia, Palestinian National Authority, Saudi Arabia, Jordan and Bahrain, gender differences were much greater, from 13 score points to 29 score points in favour of females.

In Australia, the gender differences at Year 4 have disappeared. However at Year 8, the gender equality has disappeared, with males now significantly outperforming females by 20 score points.

The trends analysis for Year 4 showed that the international average for both males and females had increased significantly from TIMSS 1994/95, by 17 score points for females and 9 score points for males. Among the 15 countries that participated in TIMSS 1994/95 and TIMSS 2002/03, Australia was the only one in which there were no significant changes for either males or females.

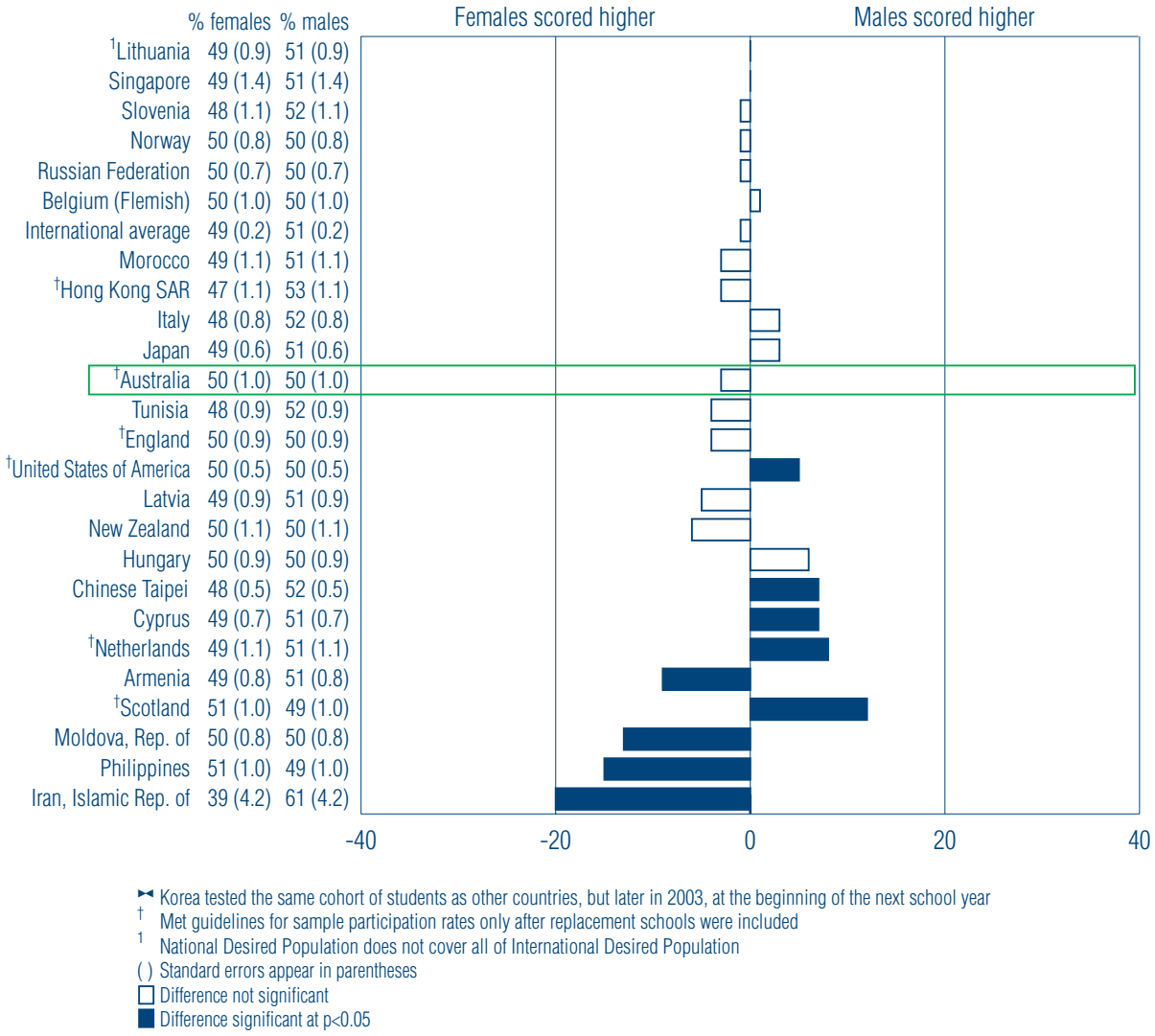
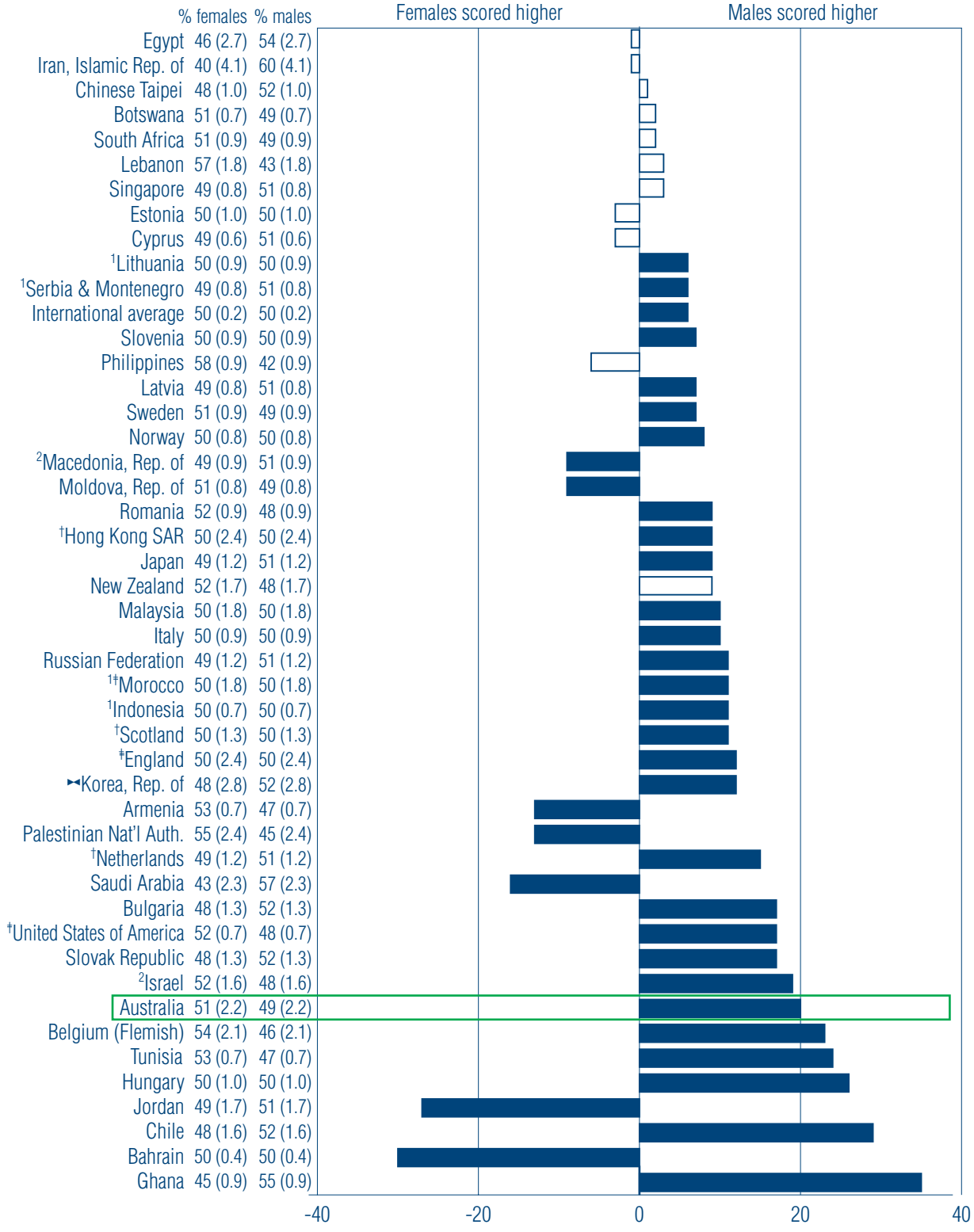


Figure 2.1 Achievement differences in science between males and females, Year 4

In Cyprus, Hong Kong SAR, Hungary, Iran, Latvia, New Zealand, Singapore and Slovenia, achievement increased significantly for both males and females. For example achievement increased by 40 score points for males and 46 score points for females in Latvia, and by 39 score points for males and 45 score points for females in Singapore. In New Zealand the changes were not as large, but were still significant; 15 score points for females and 22 score points for males. In England, females' achievement increased by a significant 17 score points, and while males' score increased, it was not a statistically significant change. In the Netherlands and in the United States of America, males' scores decreased significantly, whilst the scores of females remained virtually the same, and in Japan and Norway, the scores for both males and females decreased significantly.

At Year 8, with many more countries participating, the pattern is not as consistent. In Hong Kong SAR, Latvia, Lithuania, and the United States of America, achievement levels of both males and females have increased significantly since TIMSS 1994/95. In Hong Kong SAR, the growth in achievement has been huge – 60 score points for females and 36 score points for males. In Bulgaria, Cyprus, Norway, and the Slovak Republic, achievement levels of both males and females have declined significantly since 1994/95.

In England, Slovenia, Scotland, New Zealand, and Korea, females' achievement has increased significantly while that of males has not changed significantly. In Australia, males' achievement increased significantly, but while the achievement level of females increased, this was not significant. Australia was the only country in which this particular pattern occurred.



[⋈] Korea tested the same cohort of students as other countries, but later in 2003, at the beginning of the next school year
[†] Met guidelines for sample participation rates only after replacement schools were included
[‡] Nearly satisfied guidelines for sample participation rates only after replacement schools were included
[‡] Did not satisfy guidelines for sample participation rates
[1] National Desired Population does not cover all of International Desired Population
[2] National Desired Population covers less than 90% of National Desired Population
( ) Standard errors appear in parentheses
□ Difference not significant
■ Difference significant at p<0.05

Figure 2.2 Achievement differences in science between males and females, Year 8

How did Australian students compare with the international benchmarks in science?

To describe students' performance in science across countries, international benchmarks were developed by the International Study Centre using scale anchoring techniques (see below) and student achievement data from all countries that participated in TIMSS 2002/03. A similar exercise was carried out for both the TIMSS 1994/95 and the TIMSS 1998/99 study, and Martin, Mullis, Gonzalez, Gregory, Smith, Chrostowski, Garden and O'Connor (2000) noted that six factors seemed to differentiate between student performance at each level:

- the depth and breadth of content area knowledge
- the level of understanding and use of technical vocabulary
- the context of the problem (progressing from practical to more abstract)
- the level of scientific investigation skills
- the complexity of diagrams, graphs, tables, and textual information used
- the completeness of written responses.

Scale anchoring is a way of describing students' performance on the TIMSS 2002/03 achievement scales at both year levels in terms of the types of items that students at the particular year level answered correctly. It has both empirical and qualitative components. The empirical component used Item Response Theory to identify items that discriminated between successive points on the scale. For the empirical component, the results of all students taking part in TIMSS 2002/03 were pooled so that the levels describe what the best students at each level can do irrespective of which country they come from. For the qualitative component, subject matter specialists examined the content of the items and generalised to the students' knowledge and understanding.

Internationally it was decided that performance should be measured at four levels. These four levels summarise the achievement reached as:

- the *'Advanced International Benchmark'*, which was set at 625;
- the *'High International Benchmark'*, which was set at 550;
- the *'Intermediate International Benchmark'*, which was set at 475;
- and the *'Low International Benchmark'*, which was set at 400.

The descriptions of the levels are cumulative, so that a student who reached the high international benchmark can typically demonstrate the knowledge and skills for levels for both the intermediate and low benchmarks.

Benchmarks are only one way of examining student performance. The benchmarks discussed in this report are based solely on student performance in TIMSS 2002/03, on items that were developed specifically for the purpose of obtaining information on the science domains in the TIMSS framework. There are undoubtedly other curricular elements on which students at the various benchmarks would have been successful if they had been included in the assessment.

Benchmarks – Year 4 science

Figure 2.3 summarises what students scoring at these benchmarks typically know and can do. At Year 4, students at the advanced benchmark showed the ability to apply knowledge and understanding in beginning scientific inquiry, whereas those at the low benchmark demonstrated some elementary knowledge of the earth, life and physical sciences. More detailed descriptions of these benchmarks are also provided in Figure 2.3 and the following section of this chapter provides example test items illustrating students' performance at each level.

Australia performed moderately well against the Year 4 international benchmarks, with nine per cent of Australian Year 4 students in TIMSS 2002/03 achieving the advanced benchmark in science, slightly higher than the international average of seven per cent. Thirty-eight per cent of Australian Year 4 students achieved the high international benchmark, almost three-quarters achieved the intermediate benchmark, and 92 per cent achieved the low international benchmark. Each one of these proportions compared favourably with the international average. Figure 2.4 shows the proportion of students at each benchmark for all TIMSS 2002/03 countries.

While the proportions achieving each of the benchmarks in Australia was better than the international average, it was well short of that achieved by the highest performing countries. In Singapore, for example, one-quarter of all students in Year 4 science reached the advanced international benchmark in science, and almost two-thirds achieved the high international benchmark. This was by far the most outstanding achievement in the Year 4 achievement data; Chinese Taipei was the only other country in which more than half the students achieved at the high international benchmark, while the proportions of students achieving the high benchmark was just under 50 per cent for England, the United States of America, Japan and Hong Kong SAR.

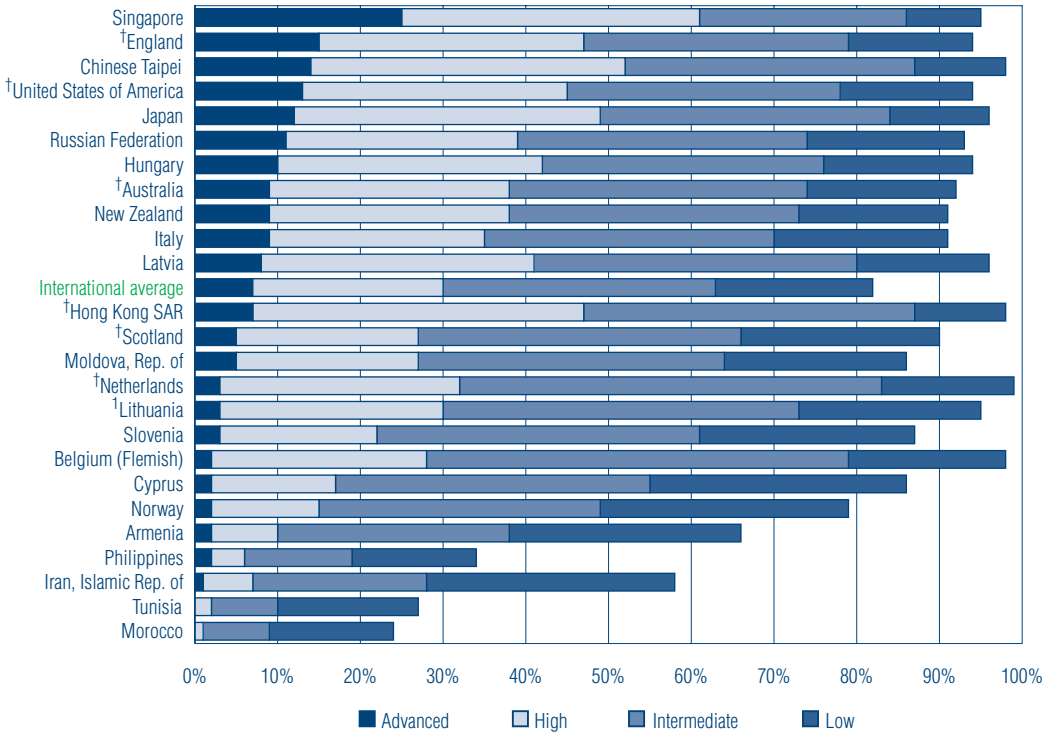
Eight countries achieved 95 per cent or greater achievement of the low international benchmark: Singapore, Chinese Taipei, Japan, Latvia, Hong Kong SAR, the Netherlands, Lithuania and Belgium (Flemish). These countries do an excellent job of educating almost all of their Year 4 students in science.

In Belgium (Flemish), and the Netherlands, fewer than three per cent of students achieve the advanced international benchmark, but fewer than two per cent fail to achieve the low international benchmark. For the lower achieving countries, however, achievement of any benchmark is problematic. In the Philippines, for example, only two per cent of students achieve the advanced international benchmark, and only one third achieve the low international benchmark.

To examine trends in achievement of benchmarks, the percentages of Year 4 Australian students reaching each of the international benchmarks is provided in Table 2.3, along with the 2002/03 international average for trend countries (i.e. countries that participated in both cycles of TIMSS), and for reference, the percentages of students reaching the benchmarks in TIMSS 1994/95, both for Australia and internationally.

Year 4	Low International Benchmark (400)	Intermediate International Benchmark (475)	High International Benchmark (550)	Advanced International Benchmark (625)
	Students have some elementary knowledge of the earth, life, and physical sciences. Students recognise simple facts presented in everyday language and context about Earth's physical features, the seasons, the solar system, human biology, and the development and characteristics of animals and plants. They recognise facts about a range of familiar physical phenomena – rainbows, magnets, electricity, boiling, floating, and dissolving. They interpret labeled pictures and simple pictorial diagrams and provide short written responses to questions requiring factual information.	*Students can apply basic knowledge and understanding to practical situations in the sciences.* Students demonstrate knowledge of some basic facts about Earth's features and processes and the solar system. They recognise some basic information about human biology and health and show some understanding of development and life cycles of organisms. They know some basic facts about familiar physical phenomena, states, and changes. They apply factual knowledge to practical situations, interpret pictorial diagrams, and combine information to draw conclusions.	*Students can apply knowledge and understanding to explain everyday phenomena.* Students demonstrate some knowledge of Earth structure and processes and the solar system and some understanding of plant structure, life processes, and human biology. They demonstrate some knowledge of physical states, common physical phenomena, and chemical changes. They provide brief descriptions and explanations of some everyday phenomena and compare, contrast, and draw conclusions.	*Students can apply knowledge and understanding in beginning scientific inquiry.* Students demonstrate some understanding of Earth's features and processes and the solar system. They can communicate their understanding of structure, function, and life processes in organisms and classify organisms according to major physical and behavioral features. They demonstrate some understanding of physical phenomena and properties of common materials. Students demonstrate beginning scientific inquiry knowledge and skills.

Figure 2.3 Descriptors of international benchmarks in science, Year 4



† Met guidelines for sample participation rates only after replacement schools were included
1 National Desired Population does not cover all of International Desired Population

Figure 2.4 Proportion of Year 4 students reaching the science international benchmarks, internationally

In Year 4 science, the proportion of Australian students reaching the advanced international benchmark has declined significantly since TIMSS 1994/95, and while there has been a slight increase in the proportion of students achieving the lower benchmarks, this was not significant. Australia is not the only TIMSS country in which the proportion of students achieving the advanced benchmark has declined since TIMSS 1994/95. In the United States of America, Japan, Scotland, the Netherlands and Norway, this was also the case. New Zealand, Latvia, Hong Kong SAR, Slovenia, and Cyprus all significantly increased the proportion of students achieving the low international benchmark from TIMSS 1994/95. Singapore, Hungary and Iran all significantly increased the proportion of students at each of the benchmark levels.

Table 2. 3 Percentages of Year 4 Australian students reaching the international benchmarks of science achievement in TIMSS 2002/03 and TIMSS 1994/95

	TIMSS 2002/03		TIMSS 1994/95	
	Proportion of Australian students (%)	International average for trend countries (%)	Proportion of Australian students (%)	International average for trend countries (%)
Advanced	9 (1.0)	8 (0.3)	13 (1.1)	9 (0.2)
High	38 (1.7)	35 (0.5)	40 (1.3)	32 (0.4)
Intermediate	74 (2.0)	71 (0.4)	72 (1.7)	63 (0.4)
Low	92 (1.1)	90 (0.3)	89 (1.1)	85 (0.3)

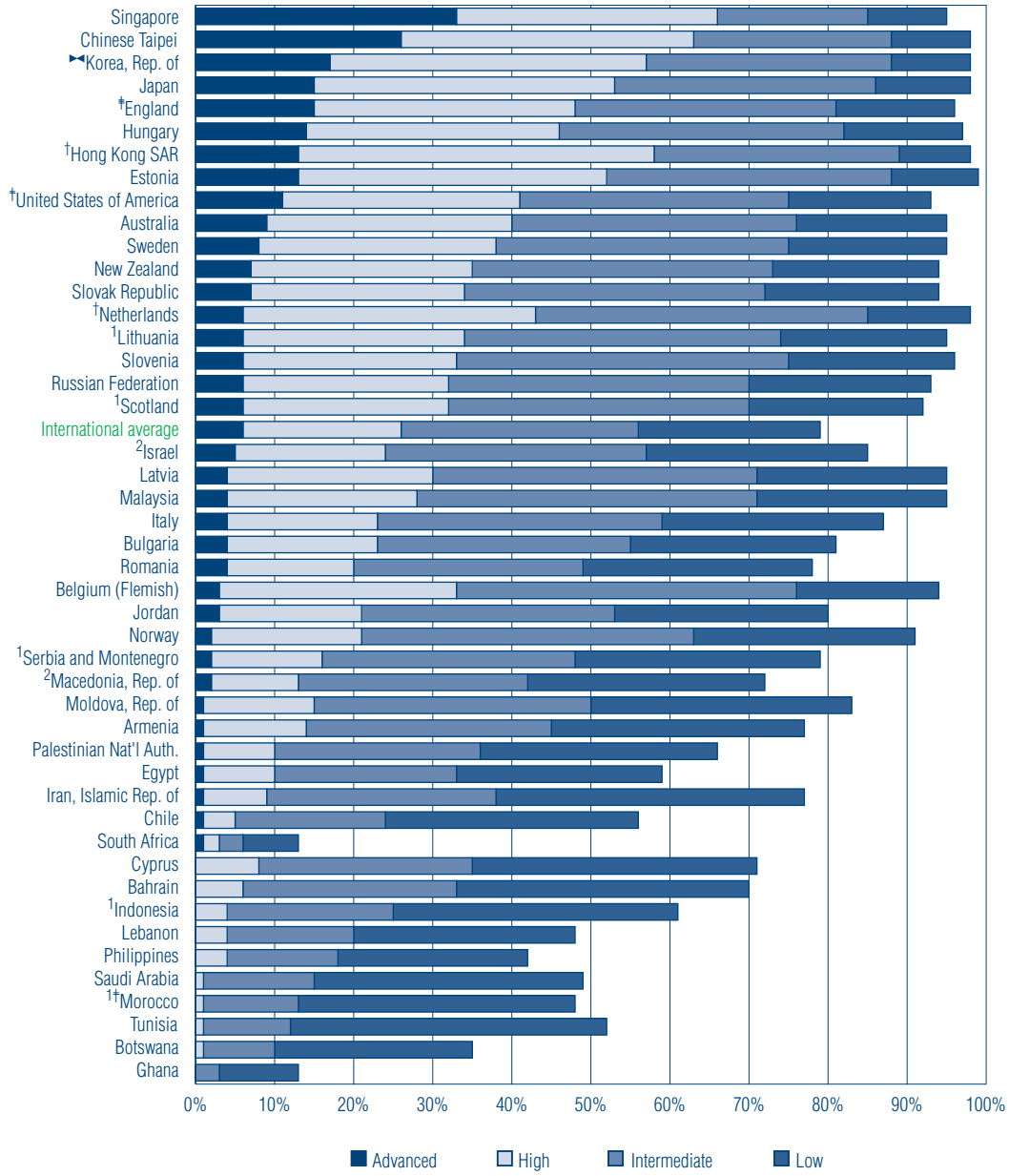
Benchmarks – Year 8 science

Figure 2.5 provides the descriptors for the international benchmarks in science at Year 8 level. At this level, performance ranged from being able to demonstrate an understanding of some complex and abstract science concepts at the advanced benchmark to being able to recognise some basic facts from the life and physical sciences at the low benchmark.

Figure 2.6 illustrates the achievement of the international benchmarks in science for all TIMSS countries. It is evident from this graph that the achievement level in some countries is outstanding – one-third of Singaporean students achieved the advanced benchmark, two-thirds the high benchmark, and all but five per cent the low international benchmark. Chinese Taipei also achieved excellent results, with a little more than one-quarter achieving the advanced benchmark, almost two-thirds the high benchmark and 98 per cent achieving the low international benchmark. In science, there appears to be a top 'group' of countries: Singapore, Chinese Taipei, Korea, Japan, Hungary, Hong Kong SAR, Estonia and England, all of which have more than ten per cent of students at the advanced benchmark, and fewer than five per cent not achieving the low benchmark.

Year 8	Low International Benchmark (400)	Intermediate International Benchmark (475)	High International Benchmark (550)	Advanced International Benchmark (625)
	Students recognise some basic facts from the life and physical sciences. They have some knowledge of the human body and heredity, and demonstrate familiarity with some everyday physical phenomena. Students can interpret some pictorial diagrams and apply knowledge of simple physical concepts to practical situations.	*Students can recognise and communicate basic scientific knowledge across a range of topics.* They recognise some characteristics of the solar system, water cycle, animals, and human health. They are acquainted with some aspects of energy, force and motion, light reflection, and sound. Students demonstrate elementary knowledge of human impact on and changes in the environment. They can apply and briefly communicate knowledge, extract tabular information, extrapolate from data presented in a simple linear graph, and interpret pictorial diagrams.	*Students demonstrate conceptual understanding of some science cycles, systems, and principles.* They have some understanding of Earth's processes and the solar system, biological systems, populations, reproduction and heredity, and structure and function of organisms. They show some understanding of physical and chemical changes, and the structure of matter. They solve some basic physics problems related to light, heat, electricity, and magnetism, and they demonstrate basic knowledge of major environmental issues. They demonstrate some scientific inquiry skills. They can combine information to draw conclusions; interpret information in diagrams, graphs and tables to solve problems; and provide short explanations conveying scientific knowledge and cause/effect relationships.	*Students demonstrate a grasp of some complex and abstract science concepts.* They can apply knowledge of the solar system and of Earth features, processes, and conditions, and apply understanding of the complexity of living organisms and how they relate to their environment. They show understanding of electricity, thermal expansion, and sound, as well as the structure of matter and physical and chemical properties and changes. They show understanding of environmental and resource issues. Students understand some fundamentals of scientific investigation and can apply basic physical principles to solve some quantitative problems. They can provide written explanations to communicate scientific knowledge.

Figure 2.5 Descriptors of international benchmarks in science, Year 8



⋈ Korea tested the same cohort of students as other countries, but later in 2003, at the beginning of the next school year
† Met guidelines for sample participation rates only after replacement schools were included
‡ Nearly satisfied guidelines for sample participation rates only after replacement schools were included
⋕ Did not satisfy guidelines for sample participation rates
1 National Desired Population does not cover all of International Desired Population
2 National Desired Population covers less than 90% of National Desired Population

Figure 2.6 Proportion of Year 8 students reaching the science international benchmarks, internationally

Table 2. 4 Percentages of Year 8 Australian students reaching the international benchmarks of science achievement in TIMSS 2002/03 and TIMSS 1994/95

	TIMSS 2002/03		TIMSS 1994/95	
	Proportion of Australian students (%)	International average for trend countries (%)	Proportion of Australian students (%)	International average for trend countries (%)
Advanced	9 (1.1)	7 (0.2)	10 (1.1)	11 (0.3)
High	40 (2.0)	30 (0.3)	36 (1.7)	37 (0.4)
Intermediate	76 (1.9)	61 (0.3)	69 (1.6)	69 (0.4)
Low	95 (0.8)	84 (0.3)	89 (1.0)	90 (0.2)

Australia's performance in science at Year 8 compares well internationally. Almost one in ten Australian students reached the advanced international science benchmark, four in ten the high international benchmark, three-quarters the intermediate benchmark and only five per cent failed to reach the low benchmark.

To examine trends in science achievement, Table 2.4 shows the percentages of Australian students achieving each of the benchmarks, the international percentages, and the corresponding percentages for TIMSS 1994/95. The proportion of Australian students reaching the low and intermediate benchmarks both increased significantly from TIMSS 1994/95, meaning that Australian schools are doing a better job of increasing science achievement for all young Australians.

Across trend countries, the proportion of students achieving at each of the lower two international benchmarks in Year 8 science has declined significantly over the eight-year period. For example in TIMSS 1994/95, 90 per cent of students reached the low international benchmark and 69 per cent the intermediate benchmark, compared with TIMSS 2002/03 in which 83 per cent met the low benchmark and 60 per cent met the intermediate benchmark.

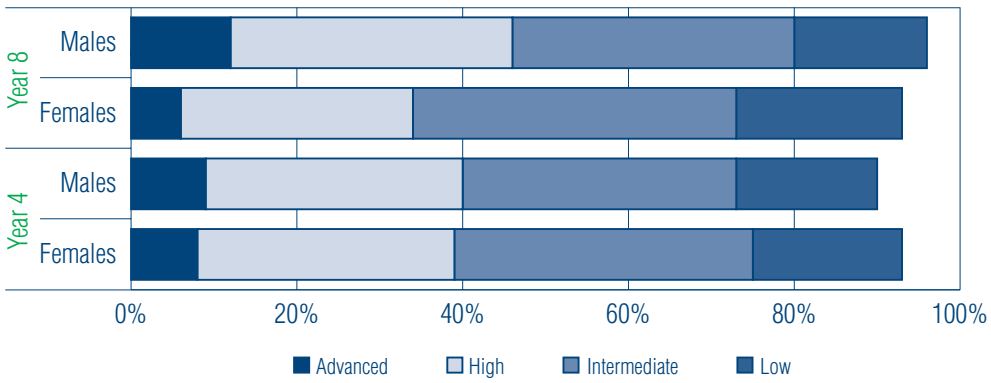


Figure 2.7 Percentage of Australian male and female students achieving at each of the international benchmarks in science

Gender differences in attainment of international science benchmarks

Figure 2.7 shows the proportion of Australian students achieving at each of the international benchmarks, by gender, for Year 4 and Year 8. At Year 4 level, about the same proportion of males and females achieved at the advanced international benchmark, and about seven per cent of females and ten per cent of males failed to achieve the low international science benchmark. At Year 8 the gender differences in achievement are more marked. Twice the proportion of male students than female students reached the advanced international benchmark, and at the other end of the achievement distribution, slightly fewer males than females failed to achieve the low benchmark. Sixty-one per cent of females achieved only the low and intermediate benchmarks, compared with 51 per cent of male students.

Benchmark examples

The remainder of this chapter provides a number of examples of the benchmarks. Several items are provided for each of the benchmarks to complement the descriptions provided and to give the reader a more concrete notion of the skills and abilities that the students at each level could demonstrate. Each example item is described, and is accompanied by the percentage of correct responses for Australia, for the highest achieving country for that particular example, for a group of other countries, including those with whom we share language or trading ties, and the international average. All examples in this section are taken from booklets completed by Australian students, and are examples of completely correct answers.

For an item to be included in a benchmark at least 65 per cent of the students scoring at the scale point corresponding to the benchmark had to have answered the item correctly and less than 50 per cent of the students at the next lowest benchmark had to have answered it correctly.

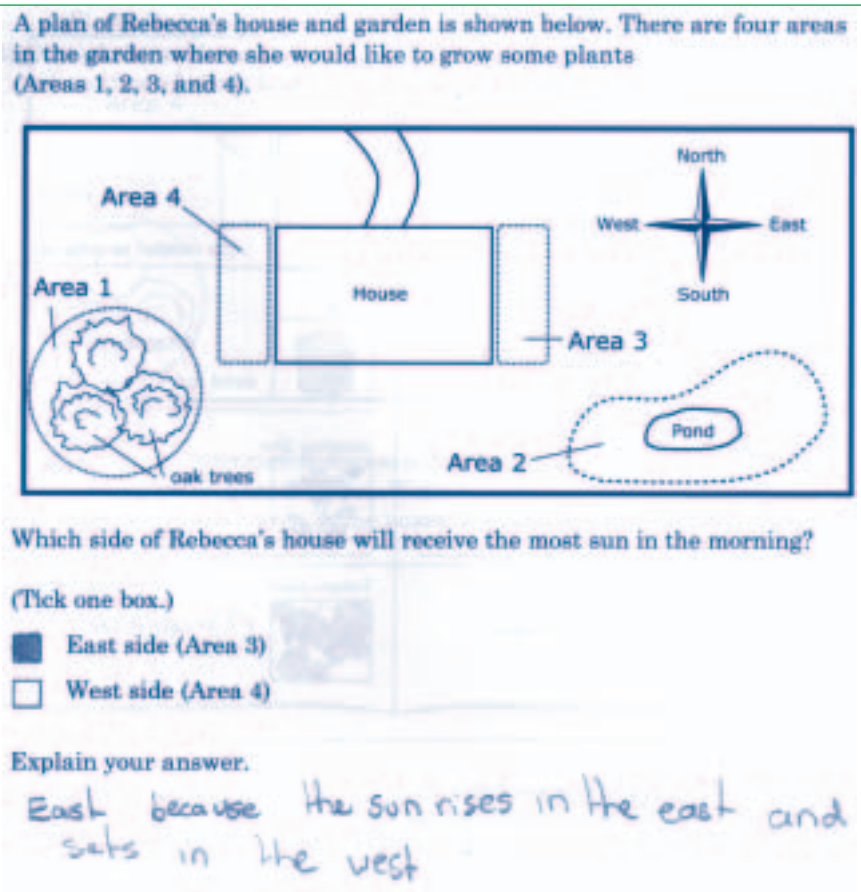
In the examples, the following conventions are used:

- Countries whose students achieved significantly higher scores than the international average are annotated with a ▲;
- Countries whose students performed at similar levels to the international average are annotated with a •;
- Countries whose students performed significantly lower than the international average are annotated with a ▼.

Year 4: Performance at the advanced international benchmark

Year 4 students achieving at the advanced international benchmark can apply knowledge and understanding in beginning scientific inquiry. They typically demonstrate success on the knowledge and skills represented by this benchmark, as well as those represented by the high, intermediate and low benchmarks.

The first example is part of an extended problem-solving and inquiry task in the earth science content area, in which students were provided with a plan of a house and garden showing the points of a compass, and were asked to explain which part of the garden would receive the most sunlight in the morning. To be awarded full credit, students needed to be able to explain that the East side of the house would receive the most sun and be able to explain this in terms of the sun rising in the East.



Content area: Earth Science

Students who reached the advanced international benchmark have some understanding of Earth's processes and features and can explain which side of a house receives most morning sun.

This item was relatively difficult for the Year 4 students, with a little more than one-quarter answering it correctly. Australian students' performance was equivalent to this, as was that of England, New Zealand, and the United States of America. Achievement by students in Scotland was significantly lower than the international average, with only about one in ten students answering this item correctly. In contrast, a little more than half of the students in Chinese Taipei and almost half of the students in Japan completed this item correctly.

Country	Percent full credit	
Highest achieving country:		
Chinese Taipei	55 (2.3)	▲
Japan	45 (2.6)	▲
Singapore	42 (2.7)	▲
United States of America	29 (1.8)	•
Australia	28 (3.4)	•
New Zealand	27 (2.7)	•
England	21 (2.9)	•
Scotland	11 (1.8)	▼
International average	26 (0.5)	

Figure 2.8 Year 4 Science Example 1: Advanced international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

In the second example, a physical science item, Year 4 students were asked to interpret tabular information about the physical properties of three materials to identify which of them were wood, rock and iron. To obtain full credit, students had to identify all three from the information given. If students identified two items only they were given partial credit for their answer.

The properties of three materials are compared in the table below.
One of the materials is wood, one is rock and one is iron.

Property	Material 1	Material 2	Material 3
Sinks in water?	Yes	No	Yes
Burns easily?	No	Yes	No
Attracted by a magnet?	Yes	No	No

Identify the three materials by filling in the spaces below.

Wood is material number: 2

Rock is material number: 3

Iron is material number: 1

Content area: Physical Science

Year 4 students reaching the advanced level were able to interpret information from a table of physical properties of three materials to identify wood, rock and iron.

Australian students' achievement in this science item was not significantly different from the international average. Almost four in ten students answered this item correctly in Australia, the United States of America, New Zealand and Scotland, while more than half of the students in England received full credit. Students in Singapore and Japan did exceptionally well on this item, with three-quarters of those in Singapore and almost seven in ten of those in Japan answering correctly.

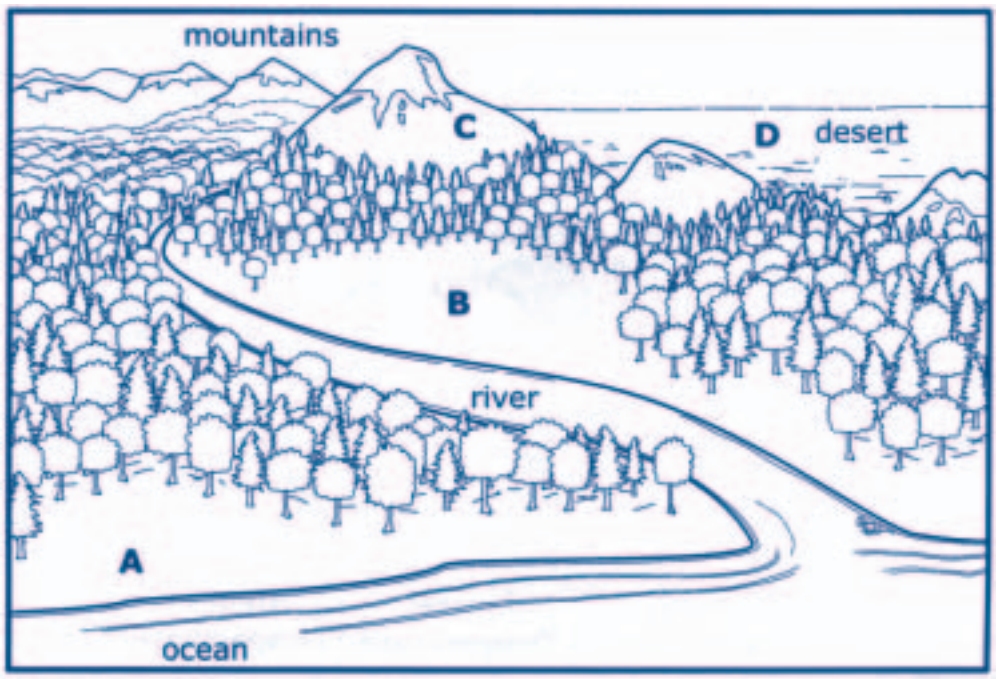
Country	Percent full credit	
Highest achieving country:		
Singapore	74 (2.3)	▲
Japan	69 (1.6)	▲
England	53 (2.5)	▲
Australia	39 (2.8)	•
United States of America	39 (1.7)	•
Scotland	38 (2.6)	•
New Zealand	37 (1.9)	•
International average	38 (0.4)	

Figure 2.9 Year 4 Science Example 2: Advanced international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

Year 4: Performance at the high international benchmark

Year 4 students who achieved at the high international benchmark demonstrated their ability to apply knowledge and understanding to explain everyday phenomena. In the first of the examples selected, from the earth science area, a diagram was provided showing a variety of landscape features, including mountains, a forest, a desert, a field, a river and the ocean, and students were asked to name the best location for growing crops.



Look at the picture above. Where is the best location to grow crops?

Ⓐ Location A
Ⓑ Location B
Ⓒ Location C
Ⓓ Location D

Content area: Earth Science

Students reaching the high international benchmark were able to recognise the best location for growing crops.

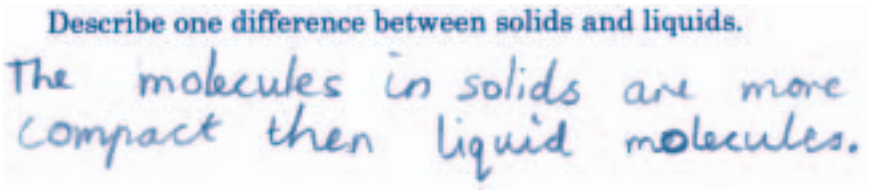
Australian students performed well on this item, with two-thirds answering correctly. This was significantly higher than the international average, as was the achievement level of all of the countries in the list to the right. Students in Japan were the highest achievers on this item, with three-quarters answering correctly.

Country	Percent full credit	
Highest achieving country:		
Japan	75 (1.6)	▲
United States of America	70 (1.1)	▲
England	69 (2.0)	▲
Scotland	68 (2.0)	▲
Australia	66 (2.5)	▲
New Zealand	63 (2.3)	▲
Singapore	62 (2.0)	▲
International average	57 (0.4)	

Figure 2.10 Year 4 Science Example 3: High international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

In the second example, a physical science item, students were asked to describe the difference between liquids and solids. Students were given credit if they referred to differences in arrangement or speed of molecules or to shape, or to consistency, ie solids are hard and liquids are runny.



Content area: Physical Science

Students at the high international benchmark in science should be able to describe one difference between a solid and a liquid.

Internationally, 44 per cent of students were able to answer this question correctly. Students in all of the countries in the table on the right had a good grasp of this question, with around two-thirds of the students in Australia and the United States of America, and almost three-quarters of the students in England and Singapore, answering correctly.

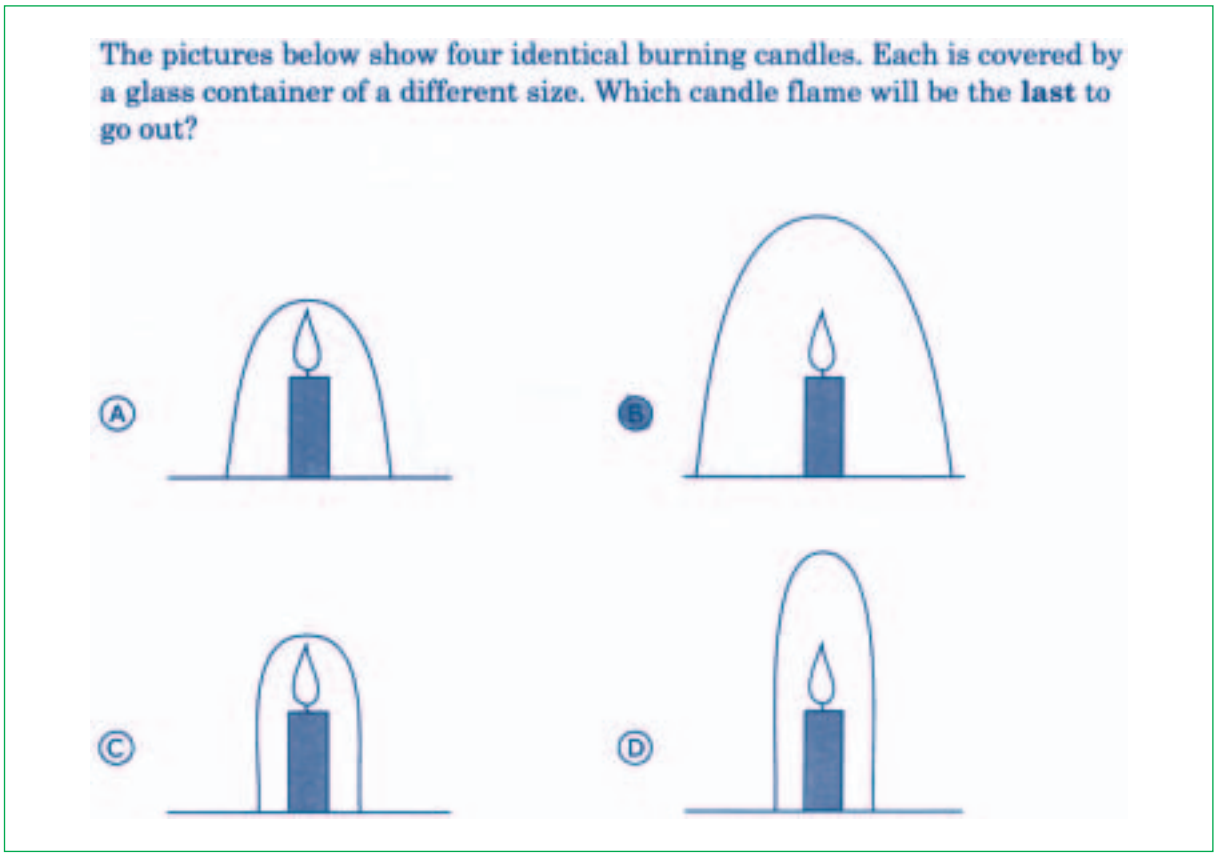
Country	Percent full credit	
Highest achieving country:		
England	74 (2.2)	▲
Singapore	73 (2.0)	▲
United States of America	67 (1.6)	▲
Australia	64 (2.1)	▲
New Zealand	62 (2.2)	▲
Japan	59 (1.8)	▲
Scotland	57 (2.1)	▲
International average	44 (0.4)	

Figure 2.11 Year 4 Science Example 4: High international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

Year 4: Performance at the intermediate international benchmark

At this level, students are able to apply basic knowledge and understanding to practical situations in the sciences. In the first example, students showed some understanding of physical phenomena, states and changes. A diagram is presented which shows four burning candles each covered by a glass container of a different size, and students had to work out which of the candles would be last to go out.



Content area: Physical Science

Students at the intermediate international benchmark were able to recognise that a candle in the largest sealed container would be the last to go out.

There were mixed results for this item. The international average was 66 per cent, and students in Australia, New Zealand, England and Scotland all scored around this average. Students in the United States of America scored significantly higher, with 72 per cent answering correctly, while those in Singapore and Cyprus, with eight in ten students answering correctly, were the highest achievers.

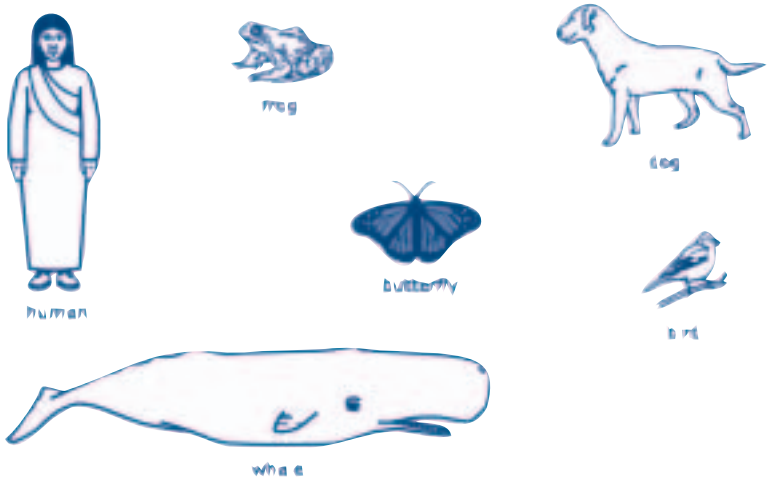
Country	Percent full credit	
Highest achieving countries:		
Cyprus	81 (2.0)	▲
Singapore	81 (2.4)	▲
United States of America	72 (1.8)	▲
England	69 (3.4)	•
Australia	66 (3.1)	•
Scotland	65 (2.6)	•
New Zealand	63 (2.9)	•
Japan	51 (3.0)	▼
International average	66 (0.6)	

Figure 2.12 Year 4 Science Example 5: Intermediate international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

The second example of the intermediate international science benchmark is a life science item, for which students needed to demonstrate knowledge of some basic facts related to human biology and health.

In this example, students were shown a diagram depicting six organisms and asked to classify them according to how they produce their young – those that give birth and those that lay eggs. Students who correctly classified all six organisms achieved full credit on this item, while those misclassifying no more than two obtained partial credit.



Some of the organisms shown above give birth to young that develop inside the mother. Some of the organisms have young that hatch from eggs that are laid outside the mother.

In the table below write down the names of the organisms that belong to each group

Organisms that give birth	Organisms that lay eggs
human dog whale	bird butterfly frog

Content area: Life Science

Students were asked to apply their knowledge of reproduction to classify these animals into those that give birth and those that lay eggs.

Internationally, 58 per cent of students achieved full credit on this item. Australian students did significantly better on this item, with 72 per cent gaining full credit. This was surpassed by Singapore, the United States of America, New Zealand and the Netherlands.

Country	Percent full credit	
Highest achieving country:		
Singapore	84 (1.3)	▲
United States of America	76 (1.1)	▲
New Zealand	74 (1.9)	▲
Australia	72 (2.6)	▲
England	67 (2.0)	▲
Japan	67 (1.8)	▲
Scotland	59 (2.1)	•
International average	58 (0.4)	

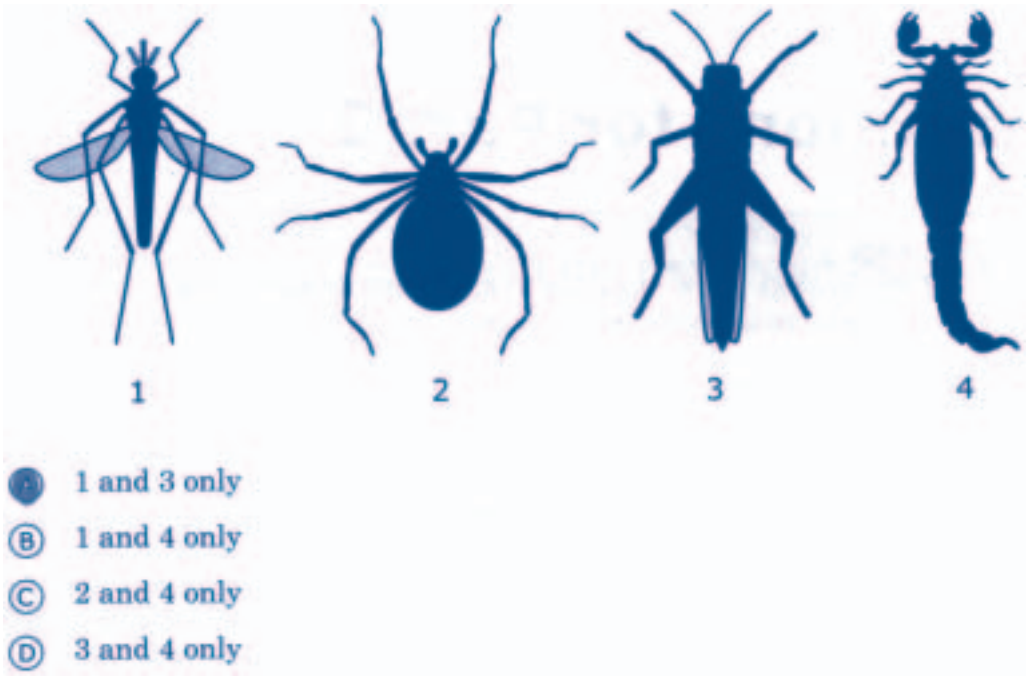
Figure 2.13 Year 4 Science Example 6: Intermediate international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

Year 4: Performance at the low international benchmark

Year 4 students achieving at the low international benchmark exhibit some elementary knowledge of the earth, life and physical sciences.

In the first example students were presented with shapes of four animals and asked to identify which were insects.



Content area: Life Science

At the low international benchmark, students should be able to identify an insect by the presence of six legs.

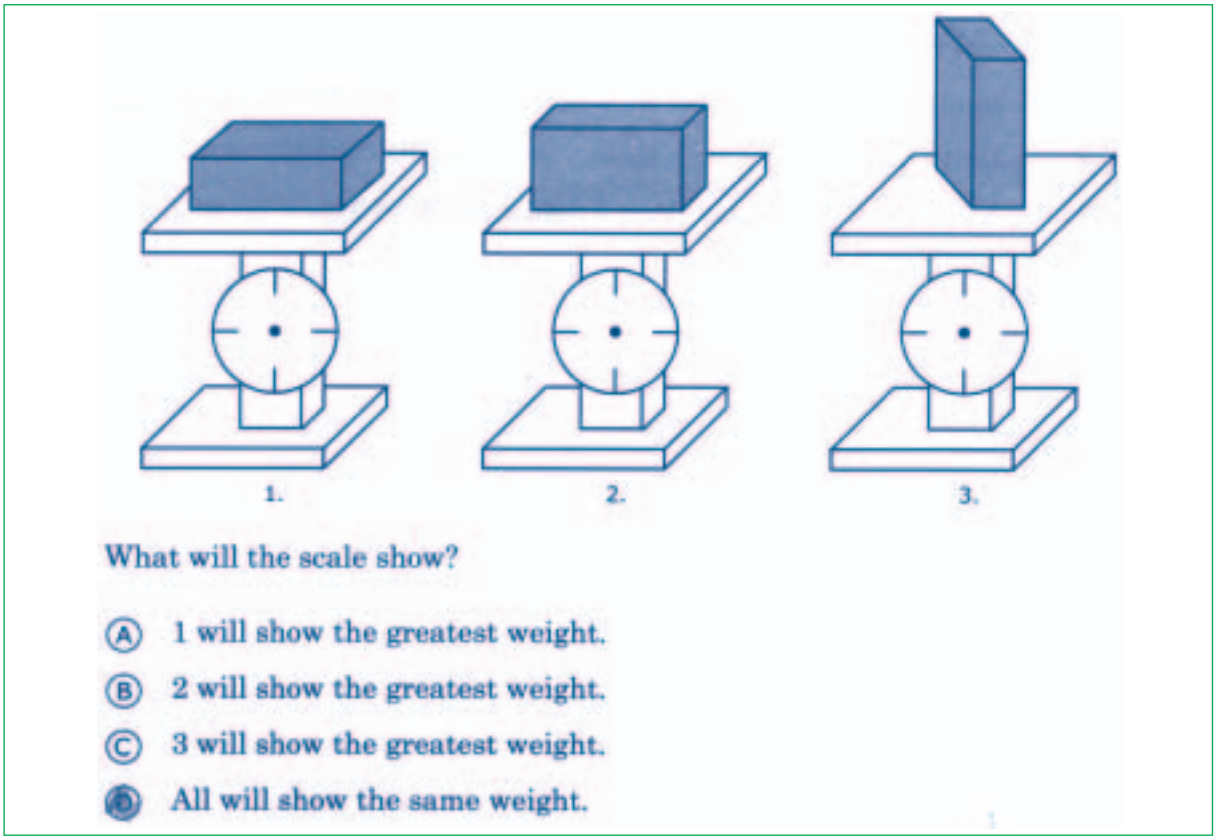
As would be expected for this low benchmark, the international average per cent correct is quite high. In the case of this item, 81 per cent of students could correctly identify an insect from the pictures provided. The only country in our comparison group not to achieve at a level significantly higher than the international average was Scotland, which was not significantly different to it. Lithuania had the highest level of achievement on this item, with 94 per cent answering correctly. More than 90 per cent of students in Singapore, Japan, Italy, the Russian Federation, the United States of America and Norway answered this item correctly.

Country	Percent full credit	
Highest achieving country:		
Lithuania	94 (1.1)	▲
Singapore	92 (1.0)	▲
Japan	91 (1.1)	▲
United States of America	91 (0.8)	▲
Australia	88 (1.6)	▲
England	86 (1.6)	▲
New Zealand	85 (1.5)	▲
Scotland	83 (1.5)	•
International average	81 (0.3)	

Figure 2.14 Year 4 Science Example 7: Low international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

Students reaching the low international benchmark also need to be able to show some elementary knowledge of everyday physical phenomena. In this example students were shown a brick in different positions on a scale, and asked what the scale will show.



Content area: Physical Science

At the low international benchmark, students need to recognise that the weight of an object is independent of its orientation on the scale.

Internationally, 72 per cent of all students were able to correctly answer this question. Students in England and Singapore performed significantly better than the average, with 76 per cent and 79 per cent of students respectively answering correctly, and almost nine in ten students in Lithuania were also able to recognise that a brick is a brick no matter which way it's turned.

Students in Australia, the United States of America and Scotland scored at around the international average, however students in New Zealand and Japan were significantly less able to answer correctly.

Country	Percent full credit	
Highest achieving country:		
Lithuania	88 (1.4)	▲
Singapore	79 (1.3)	▲
England	76 (1.7)	▲
Australia	74 (2.3)	•
United States of America	73 (1.2)	•
Scotland	68 (2.0)	•
Japan	66 (2.0)	▼
New Zealand	66 (1.6)	▼
International average	72 (0.4)	

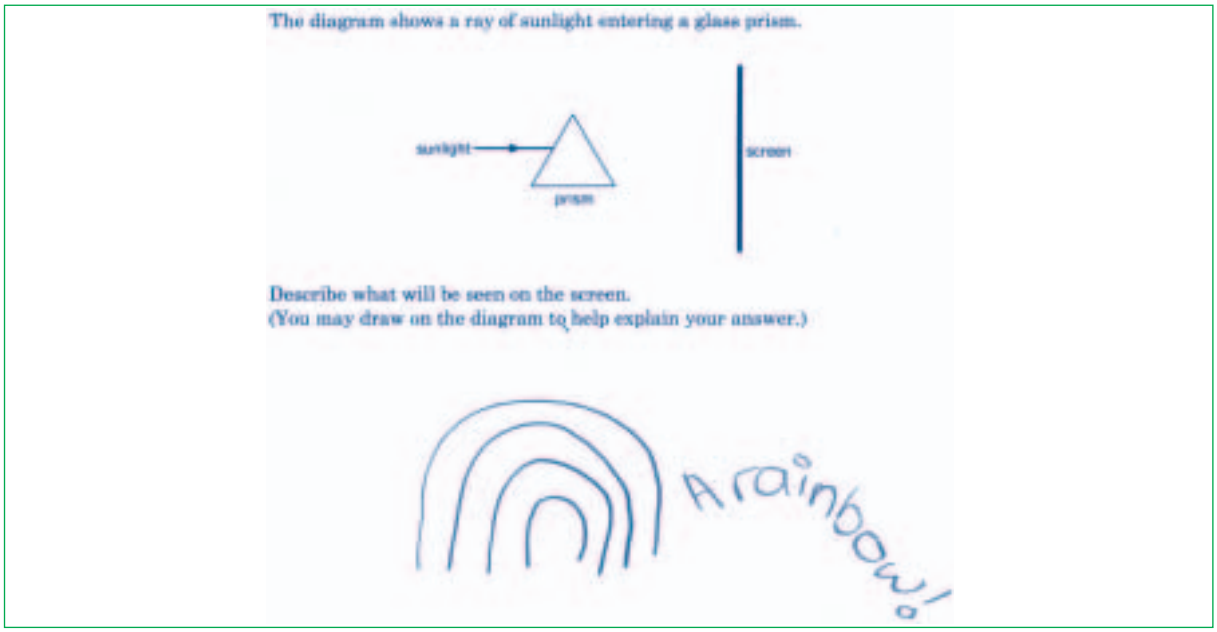
Figure 2.15 Year 4 Science Example 8: Low international benchmark

Note: United States of America, England, Scotland and Australia met sample guidelines for participation only after replacement schools were included.

Year 8: Performance at the advanced international benchmark

At the advanced international benchmark, students are able to demonstrate a grasp of some complex and abstract science concepts and can apply knowledge of earth, life, physical and environmental science. They are able to understand some fundamentals of scientific investigation and can apply basic physical principles to solve quantitative problems. Students are also able to provide written explanations to communicate scientific knowledge. They typically demonstrate success on the knowledge and skills represented by this benchmark, as well as those represented by the high, intermediate and low benchmarks.

In the first of the two examples chosen to illustrate the advanced international benchmark, students were provided with a diagram depicting a ray of sunlight entering a glass prism and a screen on the other side and were asked to describe what they saw on the screen.



Content area: Physics

To obtain full credit for this item, students had to explicitly state that different colours are seen on the screen either through a written explanation or by drawing on the diagram. Partial credit was given to students who mentioned refraction or bending of the light beam with no reference to colour.

This item was quite difficult for some students, and there was a very wide range of outcomes internationally. Almost two thirds of the students in Singapore and three quarters of the students in Korea achieved full credit for this item, compared to only around one in ten students in Japan and Indonesia. Australian students performed at around the international average, as did students in Scotland, while almost half of the students in the United States of America and England, and a little more than half of the students in Malaysia achieved full credit for this item.

Country	Percent full credit	
Highest achieving country:		
Republic of Korea	74 (2.1)	▲
Singapore	65 (2.5)	▲
Malaysia	53 (3.0)	▲
United States of America	49 (2.2)	▲
England	47 (4.7)	▲
New Zealand	43 (3.3)	▲
Scotland	28 (2.9)	•
Australia	22 (2.8)	•
Japan	10 (1.6)	▼
Indonesia	9 (1.4)	▼
International average	23 (0.3)	

Figure 2.16 Year 8 Science Example 1: Advanced international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin, Mullis, Gonzalez & Chrostowski, 2004).

In the second example depicting achievement at the advanced international benchmark, students were able to demonstrate that they could interpret information in diagrams, maps, graphs and tables to solve problems or draw conclusions. Students were provided with information in tabular form about the planets Venus and Mercury, and used this information to determine why Venus has a higher surface temperature.

The table shows some information about the planets Venus and Mercury.

	Average Surface Temperature (°C)	Atmospheric Composition	Mean Distance from the Sun (millions of km)	Time to Revolve Around the Sun (Number of Days)
Venus	470	Mostly Carbon Dioxide	108	225
Mercury	300	Trace amounts of gases	58	88

Which of the following best explains why the surface temperature of Venus is higher than that of Mercury?

Ⓐ There is less absorption of sunlight on Mercury because of the lack of atmospheric gases.

● The high percentage of carbon dioxide in the atmosphere of Venus causes a greenhouse effect.

Ⓒ The longer time for Venus to revolve around the Sun allows it to absorb more heat from the Sun.

Ⓓ The Sun's rays are less direct on Mercury because it is closer to the Sun.

Content area: Earth Science

To answer this item correctly, students had to recognise that the best explanation for the higher temperature on Venus was that there was a higher proportion of carbon dioxide in the atmosphere causing a greenhouse effect.

A little more than one-third of students (36 per cent) internationally answered this question correctly. Significantly more students in Australia, New Zealand, the United States of America and England got it right, but students in Indonesia and Malaysia had more difficulty with this item, with only 31 per cent of Indonesian students and 16 per cent of Malaysian students answering correctly.

Country	Percent full credit	
Highest achieving country:		
Korea, Republic of	70 (1.9)	▲
Singapore	60 (1.8)	▲
United States of America	49 (1.5)	▲
Australia	48 (2.6)	▲
Japan	47 (1.9)	▲
New Zealand	45 (2.4)	▲
England	44 (3.0)	▲
Scotland	40 (2.5)	•
Malaysia	31 (1.8)	▼
Indonesia	16 (1.4)	▼
International average	36 (0.3)	

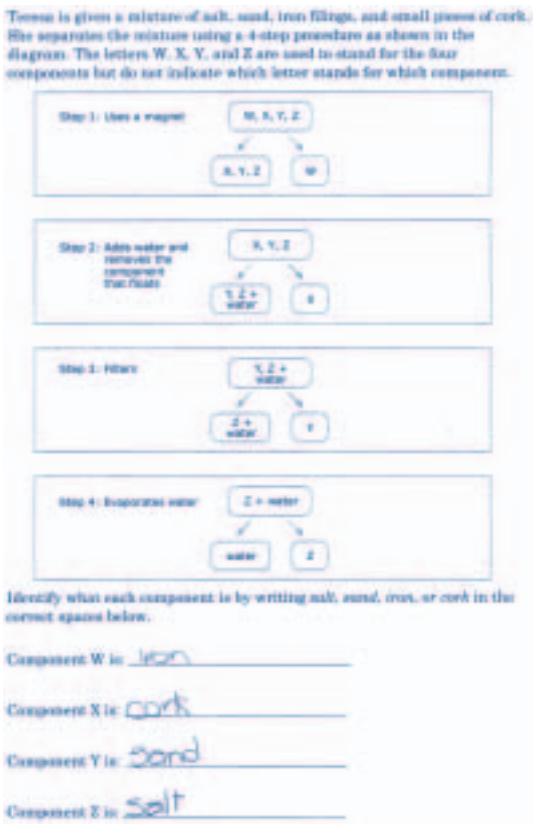
Figure 2.17 Year 8 Science Example 2: Advanced international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin et al., 2004).

Year 8: Performance at the high international benchmark

At Year 8, students achieving the high international benchmark demonstrated conceptual understanding of some science cycles, systems and principles.

In the first of the examples depicting achievement at the high international benchmark in science, students were asked to interpret a four-step decision diagram showing how to separate a mixture of sand, salt, iron filings, and small pieces of cork, into its component parts.



Content area: Chemistry

To obtain full credit for this item, students had to identify the component of the mixture obtained at each step. To gain partial credit, students needed to identify two or three components correctly.

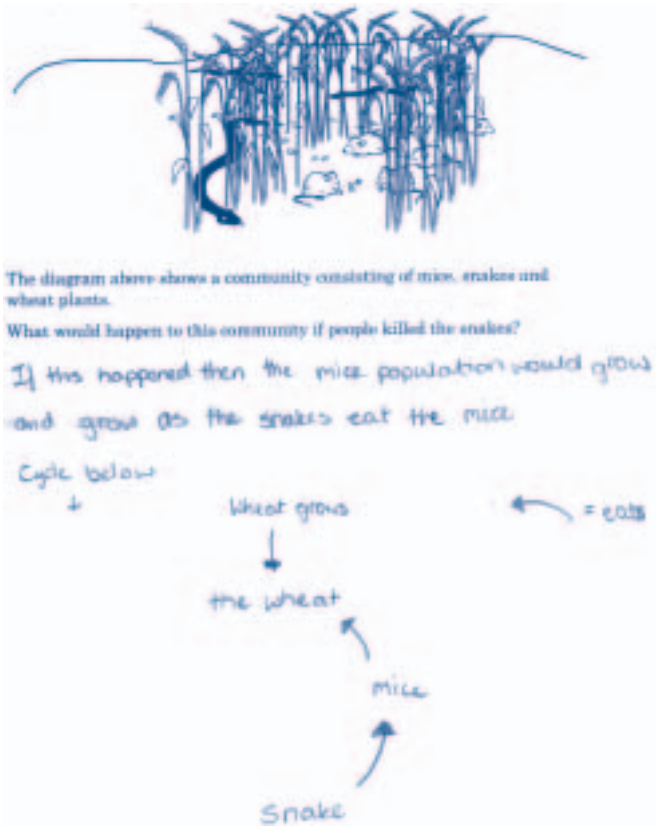
Internationally, 34 per cent of the students, on average, achieved full credit. Australia's performance was significantly higher than the international average, with 44 per cent of our students attaining full credit on this item. Singaporean students did substantially better on this item, with 68 per cent gaining full credit, as did Japanese students with 58 per cent gaining full credit. Students in the United States of America, England and New Zealand had more difficulty with this item, achieving at about the international level.

Country	Percent full credit	
Highest achieving country:		
Singapore	68 (2.2)	▲
Japan	58 (2.5)	▲
England	48 (3.8)	▲
Scotland	48 (2.9)	•
Malaysia	46 (3.0)	▲
New Zealand	46 (4.1)	•
Australia	44 (3.5)	▲
United States of America	35 (2.0)	•
Indonesia	12 (1.6)	▼
International average	34 (0.4)	

Figure 2.18 Year 8 Science Example 3: High international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin et al., 2004).

In the second example of achievement at the high international benchmark, students demonstrated some knowledge of ecosystems and food chains. In this example, students were asked to predict what would happen to a community consisting of mice, snakes and wheat plants if the snakes were all killed.



Content area: Life Science

To obtain full credit for this item, students had to explicitly mention the effect on both the mouse population and the wheat plants. If they referred to one effect but not the other then they received partial credit.

Internationally, one-third of the Year 8 students received full credit for this item. Australia's achievement was significantly better than this, with half of our students receiving full credit for this item. Students in Japan, New Zealand and Indonesia had more difficulty with this item, with about the international average of one-third of students answering correctly. Students in the United States of America did a little better, but the highest achievement was much higher than this, with 68 per cent of student in Malaysia and 78 per cent of students in Singapore gaining full credit.

Country	Percent full credit	
Highest achieving country:		
Singapore	78 (1.8)	▲
Malaysia	68 (2.1)	▲
England	57 (2.4)	▲
Australia	50 (2.3)	▲
United States of America	44 (1.7)	▲
Scotland	42 (2.5)	▲
New Zealand	35 (3.2)	•
Japan	31 (1.6)	•
Indonesia	30 (1.7)	•
International average	33 (0.3)	

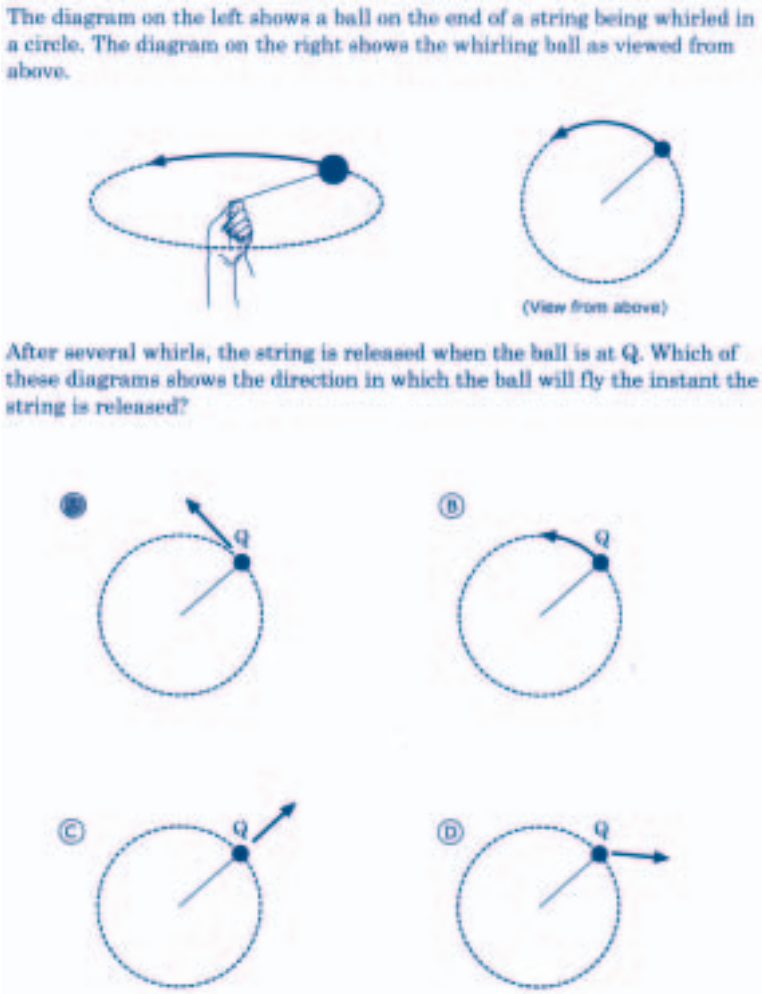
Figure 2.19 Year 8 Science Example 4: High international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin et al., 2004).

Year 8: Performance at the intermediate international benchmark

Year 8 students achieving at the intermediate international benchmark could recognise and communicate basic scientific knowledge across a range of topics.

The first example is from physics, and depicts a ball on the end of a string being whirled in a circle. It requires students to demonstrate some knowledge of circular motion.



Content area: Physics

Students were asked to use their knowledge of circular motion to recognise that the ball will fly in a straight line when the ball is released.

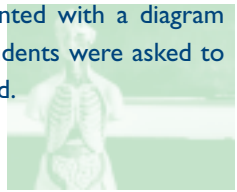
This item was relatively easy for many students. The international average was 60 per cent of students answering correctly, and exactly half of the participating countries achieved significantly above this average, with between 68 per cent and 87 per cent of students answering correctly. Australia's average of 77 per cent was similar to that of most of our comparison countries.

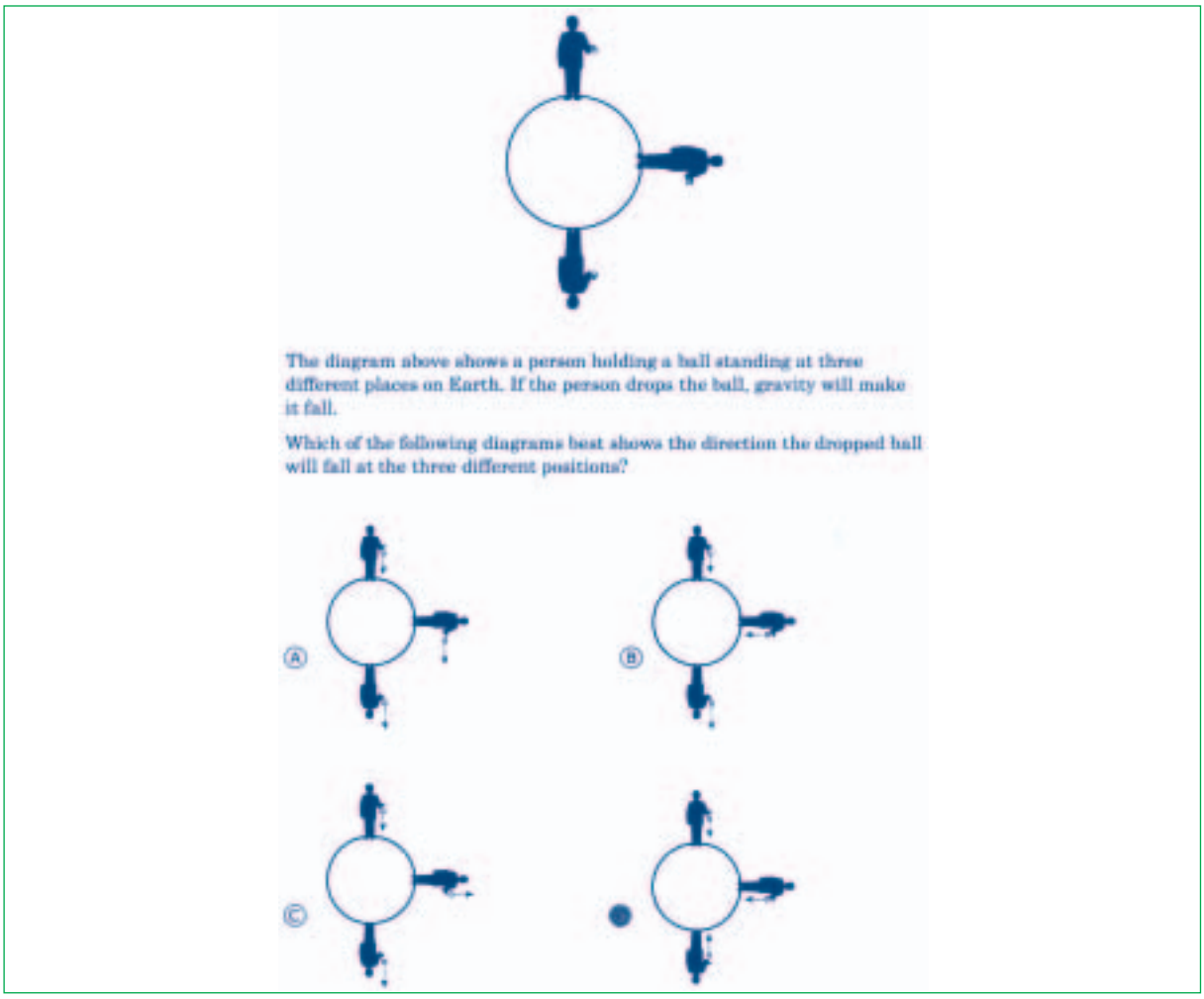
Country	Percent full credit	
Highest achieving country:		
Korea, Republic of	87 (1.2)	▲
Australia	77 (1.9)	▲
Japan	77 (1.5)	▲
New Zealand	77 (2.4)	▲
Scotland	77 (1.4)	▲
United States of America	76 (1.4)	▲
Malaysia	75 (1.8)	▲
England	74 (2.0)	▲
Indonesia	47 (1.9)	▼
International average	60 (0.3)	

Figure 2.20 Year 8 Science Example 5: Intermediate international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin et al., 2004).

The second example addresses students' understanding of gravity. Students were presented with a diagram showing a person holding a ball while standing at three very different places on earth. Students were asked to choose which of four alternatives best describe what would happen when a ball is dropped.





Content area: Earth Science

To answer correctly, students had to demonstrate an understanding of gravity by selecting the diagram showing that the ball will always drop towards the centre of the earth.

This was also a relatively easy item, with 70 per cent of students internationally answering correctly. Australia's average was significantly higher, with 79 per cent, as was that of the United States of America, England, New Zealand, Malaysia and Singapore, while the highest achieving country was Japan, with 92 per cent of students gaining credit on this item.

Country	Percent full credit	
Highest achieving country:		
Japan	92 (1.2)	▲
Malaysia	86 (1.5)	▲
New Zealand	81 (2.9)	▲
Singapore	80 (1.7)	▲
Australia	79 (2.5)	▲
England	78 (3.0)	▲
United States of America	75 (1.8)	▲
Scotland	73 (2.9)	•
Indonesia	62 (2.2)	▼
International average	70 (0.4)	

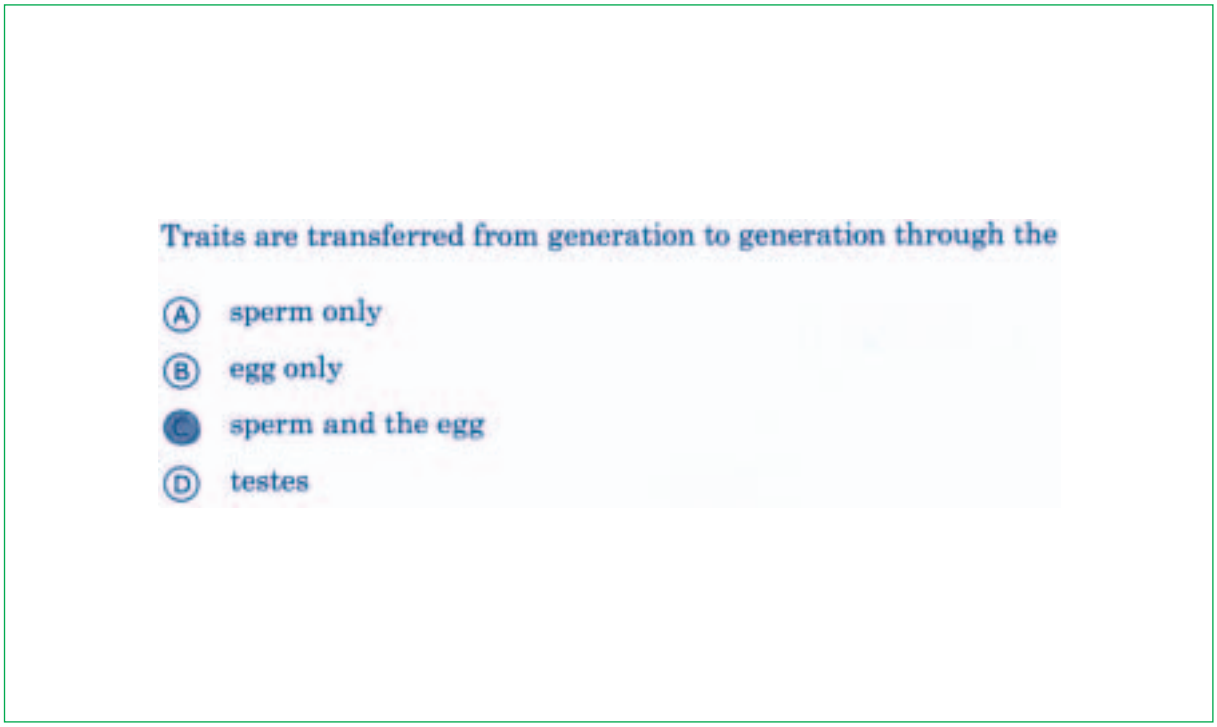
Figure 2.21 Year 8 Science Example 6: Intermediate international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin et al., 2004).

Year 8: Performance at the low international benchmark

At the low international benchmark, students can recognise some basic facts from the life and physical sciences. They have some knowledge of the human body and heredity, and are familiar with some physical phenomena.

In the first example illustrating achievement at the low international benchmark, students were asked to demonstrate some knowledge of how traits are passed from one generation to the next.



Content area: Life Science

In this item, students need to be able to demonstrate that they understand traits are transferred to offspring through the sperm and egg.

As would be expected, most students were able to choose the correct answer on this item. Internationally, three-quarters of students were able to do so, with the proportion of Australian students answering correctly similar to this. Students in Japan and New Zealand also achieved at around the international average, while those in the United States of America, England, Scotland, Malaysia and Singapore achieved at a higher level. Students in Chinese Taipei and Hong Kong SAR, were most likely to be able to answer this question, with 97 per cent of students in each country answering correctly.

Country	Percent full credit	
Highest achieving countries:		
Chinese Taipei	97 (0.7)	▲
Hong Kong SAR	97 (0.6)	
England	88 (1.5)	▲
Singapore	86 (1.0)	▲
United States of America	86 (1.2)	▲
Scotland	83 (1.8)	▲
Malaysia	79 (1.4)	▲
Japan	76 (1.8)	•
Australia	73 (2.2)	•
New Zealand	70 (2.6)	•
Indonesia	67 (1.9)	▼
International average	74 (0.3)	

Figure 2.22 Year 8 Science Example 7: Low international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin et al., 2004).

In this last example of achievement at the low international benchmark in science, students were asked to identify the diagram showing the correct arrangement of batteries in a torch.

The diagrams show a torch and three ways to put batteries in it.

In order to make the torch work, which way must the batteries be placed?

Ⓐ Only as in K
Ⓑ Only as in L
Ⓒ Only as in M
Ⓓ None of these ways would work.

Content area: Physics

Students were asked to pick the correct arrangement of batteries in order for a torch to work.

This item was quite easy for most students to answer correctly, with 85 per cent doing so internationally. Australia's results were exactly this, and were similar to those of Scotland, New Zealand and Indonesia. Students in Singapore, Japan, England and Malaysia all achieved at a level higher than this, with more than 90 per cent answering correctly.

Country	Percent full credit	
Highest achieving country:		
Singapore	97 (0.5)	▲
England	95 (1.0)	▲
Japan	93 (0.9)	▲
Malaysia	91 (1.0)	▲
United States of America	89 (0.8)	▲
New Zealand	88 (2.0)	•
Australia	85 (1.8)	•
Scotland	84 (1.6)	•
Indonesia	84 (1.2)	▼
International average	85 (0.2)	

Figure 2.23 Year 8 Science Example 8: Low international benchmark

Note: England did not satisfy guidelines for sample participation rates. United States of America nearly satisfied guidelines for sample participation rates only after replacement schools were included. Hong Kong SAR, Netherlands, and Scotland met guidelines for sample participation rates only after replacement schools were included. In Indonesia, the National Desired Population does not cover all of the International Desired Population (see International Report: Martin et al., 2004).

Summary

This chapter has described Australia's science performance in Year 4 and Year 8 in the context of international results. Australian students acquitted themselves well in science, with the performance of Australian students at both year levels significantly higher than the international average. The highest-scoring countries at both year levels were Singapore and Chinese Taipei.

It is not really possible to describe Australia's position in terms of 'rankings' of countries, as the participating countries have changed substantially since TIMSS 1994/95. However it is possible to outline a few changes in relative standings at each year level.

At Year 4, Hong Kong SAR and Latvia were significantly lower than Australia in 1994/95: in 2002/03 their achievement level was significantly higher than Australia's. Hungary and New Zealand were significantly lower than Australia in 1994/95: in 2002/03 there is no significant difference to Australia. Singapore, the United States of America and England had similar scores to Australia in 1994/95, but in 2002/03 their achievement was significantly higher than Australia.

At Year 8, Hong Kong SAR was significantly lower than Australia in 1994/95 and in 2002/03 is significantly higher. The scores of New Zealand and Lithuania were significantly lower and their difference is now the same as that of Australia. England and Hungary scored the same as Australia in 1994/95 and were significantly higher in 2002/03.

In TIMSS 1994/95, males scored significantly higher in science than females, but there was no significant difference at Year 8. In TIMSS 2002/03, the gender differences at Year 4 were not apparent; however males scored a significant 20 scale point higher than females, on average, in Year 8 science.

International benchmarks were developed by the International Study Centre; these are described in this chapter and elaborated with examples of each of the benchmark levels. Australia's performance was similar to the international average at Year 4, and slightly better at Year 8. At Year 4, there were nine per cent of Australian students reaching the advanced benchmark, 38 per cent reaching the high benchmark, 74 per cent reaching the intermediate and 92 per cent reaching the low international benchmark. The proportion of Australian Year 4 students reaching the advanced international benchmark had declined significantly since TIMSS 1994/95. At Year 8, there were nine per cent of students reaching the advanced benchmark, 40 per cent reaching the high benchmark, 76 per cent reaching the intermediate and 95 per cent reaching the low international benchmark.

The next chapter, Chapter 3, presents results within Australia, focussing on performance in the science content areas and differences in achievement between states.

Chapter 3
Australian students' achievement in science

Chapter 3
Australian students' achievement in science

In Chapter 2 the achievement results for Australia were presented in an international context, comparing the results from Australian students to results from each of the other participating countries as well as to the international average. This chapter presents results in the science content areas for both Year 4 and Year 8, and results on achievement measures for the Australian states.

The TIMSS 2002/03 science assessments at both year levels were designed to allow comparisons between countries as much as is possible. The five content areas and the topics for each area in science are:

- *Life Science*
  - types, characteristics, and classification of living things,
  - structure, function, and life processes in organisms,
  - cells and their functions,
  - development and life cycles of organisms,
  - reproduction and heredity,
  - diversity, adaptation and natural selection,
  - ecosystems, and
  - human health.

  At Year 4, the topic of cells and their functions is not included.
- *Chemistry*
  - classification and composition of matter,
  - particulate structure of matter,
  - properties and uses of water,
  - acids and bases, and
  - chemical change.

  At Year 4, the topics of the particulate nature of matter, and acids and bases are not included.
- *Physics*
  - physical states and changes in matter,
  - energy types, sources and conversions,
  - heat and temperature,
  - light,
  - sound and vibration,
  - electricity and magnetism, and
  - forces and motion.

  At Year 4, *physics* is not reported separately, but combined with *chemistry* as *physical sciences*. At this year level, the topic of sound and vibration is not included.
- *Earth Science*
  - Earth's structure and physical features,
  - Earth's processes, cycles and history, and
  - Earth in the solar system and the universe.
- *Environmental Science*
  - changes in population,
  - use and conservation of natural resources, and
  - changes in environment.

  At Year 4, *environmental science* is not assessed. However there were a few items in the Year 4 assessment that addressed the use and conservation of natural resources and changes in environments. These were reported as part of *life science*.

How does achievement differ internationally across content areas?

To provide a basis of comparison for the performance of each country in each content area, the international average for each content area was scaled to be 489 for Year 4 and to 474 for Year 8 science. At both year levels, countries scoring the highest in the overall science assessment tended also to be the highest scoring countries in each of the major content areas, although not necessarily in the same order.

At Year 4, with fewer and less diverse countries, the differences in achievement were not particularly large. The largest difference in average score between highest and lowest scoring country was 269 score points in *physical science*. For the other two areas, the differences were 258 for *life science*, and 248 for *earth science*.

At Year 8 level there were more substantial differences between countries in content areas. The largest difference in average achievement between the highest and lowest scoring countries was 340 score points in *physics*, with the highest scores in Singapore and Korea and the lowest in Ghana. Score differences in the other content areas were 319 for *life science*, 311 for *earth science*, 308 for *chemistry*, and 307 for *environmental science*.

How did Australian students perform in the science content areas?

Australian students scored at a level significantly higher than the international average in all of the content areas at both Year 4 and Year 8 in science.

Figure 3.1 shows the average and confidence intervals for each of the Year 4 science content areas, and includes the confidence interval for the international average as the shaded bar on the graph.

At Year 4, Australian students scored highest in *life science*, and the scores in other subject areas were very similar to each other. At Year 8 level, the highest average score was in the area of *environmental science*. Performance in *earth science* and *life science* was also strong, and the weakest area was that of *chemistry*.

Figure 3.2 presents the averages and confidence intervals for Year 8 students in the science content areas and shows that Australian Year 8 students' achievement level was significantly higher than the international average in all science content areas.

Achievement in science content areas by gender

In TIMSS science at Year 4, no gender differences were apparent, however at Year 8, males significantly out-performed females.

Table 3.1 provides achievement in each of the science content areas, by year level, for males and females, as well as the overall averages for each area. It is clear from this table that gender differences within Australia for Year 4 are quite small. At this year level, the largest gender difference internationally was in the content area of life science, in which the score of 491 attained by females was significantly higher than the 487 attained by males. Australian students' results were somewhat similar to the international results, with a significant difference in favour of females in this area. In other content areas at Year 4 the achievement scores for males and females in Australia are not significantly different.

In contrast, Table 3.1 shows that some of the gender differences at Year 8 are quite large. The largest gender difference internationally was in the content area of *earth science*, in which the males' score was 16 score points higher than that of females. In Australia, males outscored females in all of the content areas, and significantly so in four. Even in the content area of *life science*, in which internationally

Table 3.1 Average achievement in science content areas, internationally and Australian, total and by gender

Content area	Australian			International		
	Females average	Males average	All average	Females average	Males average	All average
Year 4						
Life Science	**527 (3.5)**	**520 (4.9)**	523 (3.8)	**491 (0.8)**	**487 (0.8)**	489 (0.7)
Physical Science	518 (3.8)	518 (5.1)	518 (3.9)	**490 (0.9)**	**488 (0.8)**	489 (0.7)
Earth Science	519 (4.0)	518 (5.7)	518 (4.1)	**488 (0.9)**	**490 (0.8)**	489 (0.7)
Year 8						
Life Science	527 (4.6)	538 (4.5)	532 (3.8)	**476 (0.6)**	**473 (0.6)**	474 (0.5)
Chemistry	**498 (5.1)**	**515 (4.9)**	506 (3.8)	474 (0.6)	474 (0.6)	474 (0.5)
Physics	**510 (4.5)**	**532 (4.5)**	531 (4.2)	**468 (0.6)**	**480 (0.6)**	474 (0.5)
Earth Science	**516 (4.8)**	**547 (4.9)**	531 (4.2)	**466 (0.6)**	**482 (0.6)**	474 (0.5)
Environmental Science	**528 (4.4)**	**543 (4.0)**	536 (3.4)	**472 (0.6)**	**476 (0.6)**	474 (0.5)

Figures in bold indicate where a significant difference exists

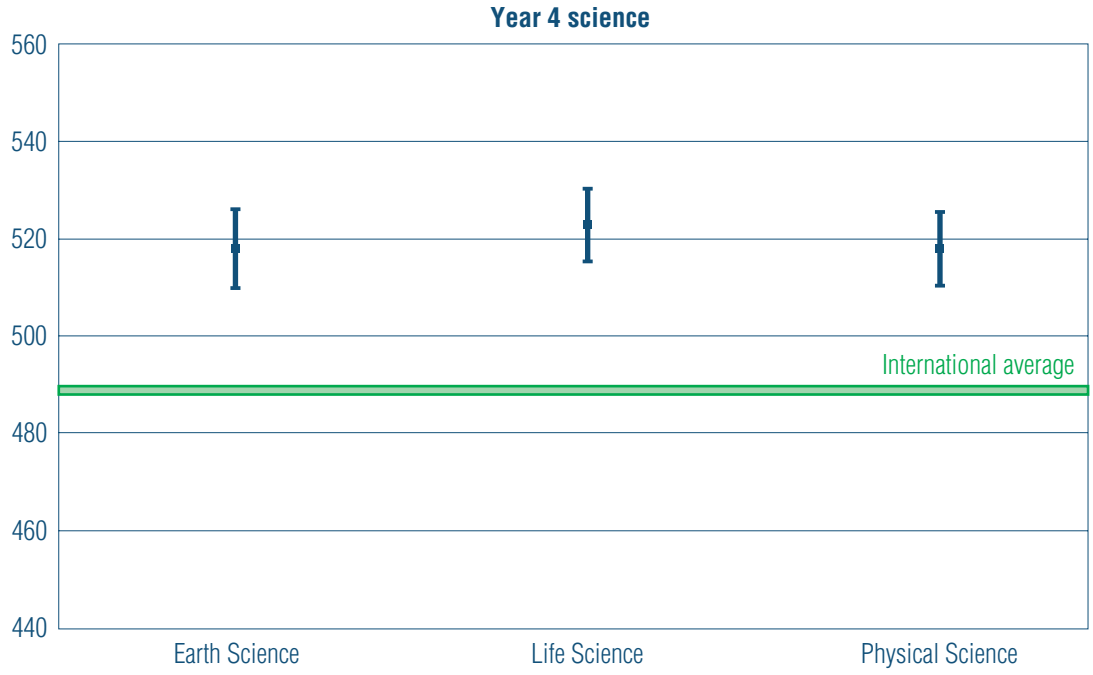


Figure 3.1 Australian Year 4 students' performance in science content areas

females scored significantly higher than males, Australian male students' score was higher than that of females, although this was not significant.

Results in the Australian states

Schools were oversampled in the smaller states of Australia: South Australia, Western Australia, the Northern Territory, Tasmania and the Australian Capital Territory, to enable reliable estimates of achievement for each state to be made.

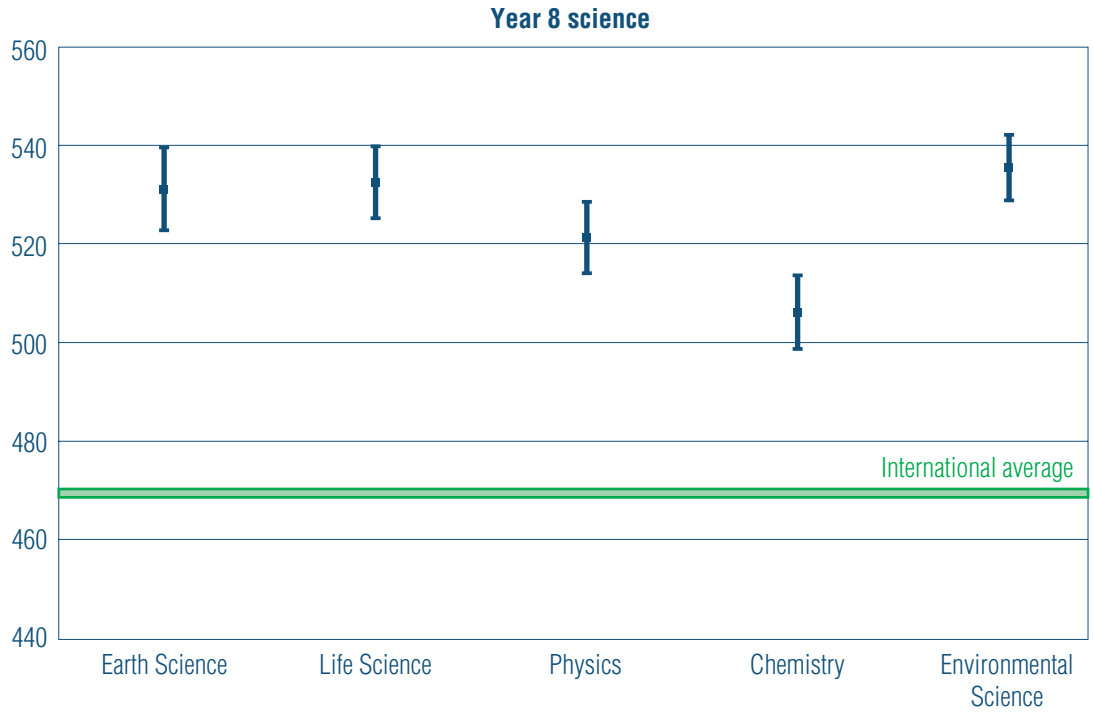


Figure 3. 2 Australian Year 8 students' performance in science content areas

While it is easier to compare the Australian states than to compare countries, there are still structural and curriculum differences to take into account. In Chapter 1 reference was made to the different school starting ages in each state and territory, and to the differing roles of the first year of school. In some parts of Australia, students enter school as they turn five, so may only complete one term of a preparatory year before moving on to the first year.

In other parts of Australia many children enter the school system before they turn five, and have a whole year at school before entering the first year, whilst in other areas children move straight into the first year. There are also differing points of transition from primary to secondary schooling. In some states it is at the end of Year 6, others at the end of Year 7. These differences mean that by settling on one year at each population level (Year 4 for population 1 and Year 8 for population 2), as the IEA have stipulated for TIMSS 2002/03, there are some differences between states that should be borne in mind when discussing results:

- students in some states will be younger than those in other states and thus may be at different maturational stages;
- students in some states will have had more formal schooling experiences than students in other states; and
- students in some states in Year 8 will have had two years of mathematics and science with specialist teachers, whereas for those in other states, it will be their first year of specialised teaching.

However by choosing to sample Year 8 in each state, the samples have one major factor in common – all students have four years left to the completion of secondary schooling, which is Year 12 in every state.

State results – Year 4

Table 3.2 provides the average achievement for each state for Year 4 science, and also presents the multiple comparisons of results in science within Australia. Figure 3.3 illustrates the averages and confidence intervals for Year 4 achievement in mathematics for students in each state, and provides, for comparison, the confidence interval for Australia and also the international confidence interval.

The comparison of results within Australia presented in Table 3.2 shows that there is almost no variation amongst states in science achievement at Year 4. The only difference was that average achievement in Western Australia was lower than average achievement in the Australian Capital Territory.

In comparison to TIMSS 1994/95, this represents some change in achievement levels between states. When making comparisons with that study, it is important that comparisons are made with the Year 4 cohort only, as presented in Table A.12 of the TIMSS 1994/95 Australia population 1 report (Lokan, Ford & Greenwood, 1997). In those comparisons, students in the Australian Capital Territory outperformed those in all other states, students in the Northern Territory were outperformed by students in almost every state, and students in Queensland were also outscored by students in Western Australia, Victoria and New

Table 3.2 Year 4 science achievement by state

State	Average	se	ACT	VIC	NSW	TAS	SA	QLD	NT	WA
Australian Capital Territory	547	9.7		•	•	•	•	•	•	▲
Victoria	528	6.8	•		•	•	•	•	•	•
New South Wales	526	10.1	•	•		•	•	•	•	•
Tasmania	517	11.6	•	•	•		•	•	•	•
South Australia	515	8.5	•	•	•	•		•	•	•
Queensland	513	7.7	•	•	•	•	•		•	•
Northern Territory	503	13.8	•	•	•	•	•	•		•
Western Australia	502	7.3	▼	•	•	•	•	•	•	

▲ score significantly higher than that for comparison state
• score not significantly different than that of the comparison state
▼ score significantly lower than that for comparison state
Note: Read **across** the row to compare a state's performance with the performance of each state as listed in the column headings

[1] The statistical technique used adjusts for multiple comparisons, i.e. comparing results of several groups simultaneously. Tests of significance were adjusted for the number of simultaneous comparisons being made, so that the probability level remained at 0.05.

South Wales. In TIMSS 1994/95 there were large differences apparent between the states in Year 4 science, this is certainly not the case in TIMSS 2002/03.

While there appear to be differences in scores both in TIMSS 1994/95 and in the present study, it must be emphasised that if the differences are not statistically significant, they could well be an artefact of sampling or measurement error. It is only when there is a significant difference that we are able to say that, with 95 per cent probability, the differences reflect actual differences in the population under consideration.

Figure 3.3 shows that the confidence interval for the Northern Territory is the only one that overlaps the confidence interval for the international average, and the score for the Australian Capital Territory is the only one that does not largely overlap the confidence interval for the national average. The science scores are quite remarkably similar nationally at Year 4 level.

Table 3.3 shows where achievement for each state fits into the international picture of achievement in science. The confidence intervals associated with the Australian states are larger than those for the country averages because of the smaller number of schools in the state samples. Most of the Australian states scored comparatively well in science at Year 4 level.

Australia's highest scoring state, the Australian Capital Territory, has the third highest ranking internationally. As significance testing found that the score for the Australian Capital Territory was not significantly different from those of either Singapore or Chinese Taipei, the Australian Capital Territory can be thought of as having the equal highest ranking internationally. The scores for students in Victoria and New South Wales were not significantly different to those in the countries in the group above them – Hungary through to Japan, and the scores of Tasmania, South Australia, Queensland, the Northern Territory and Western Australia were statistically similar to those in Belgium (Flemish), New Zealand, the Netherlands and the Russian Federation, as well as to the Australian average.

A comparison with science achievement patterns in TIMSS 1994/95 can be made. However, achievement in the TIMSS 1994/95 report was derived from a combination of upper and lower year scores, hence the sample was composed of students from Year 3, Year 4 and Year 5. Given this caveat, however, the data provides a rough 'yardstick' for comparison. The highest scoring four states in science in TIMSS 1994/95 were Western Australia, South Australia, Queensland, and the Australian Capital Territory, and these states outperformed all countries other than Korea. In the TIMSS 2002/03 assessment, three of these states, Western Australia, South Australia and Queensland are around the middle of the distribution, while Victoria, New South Wales and Tasmania have improved achievement.

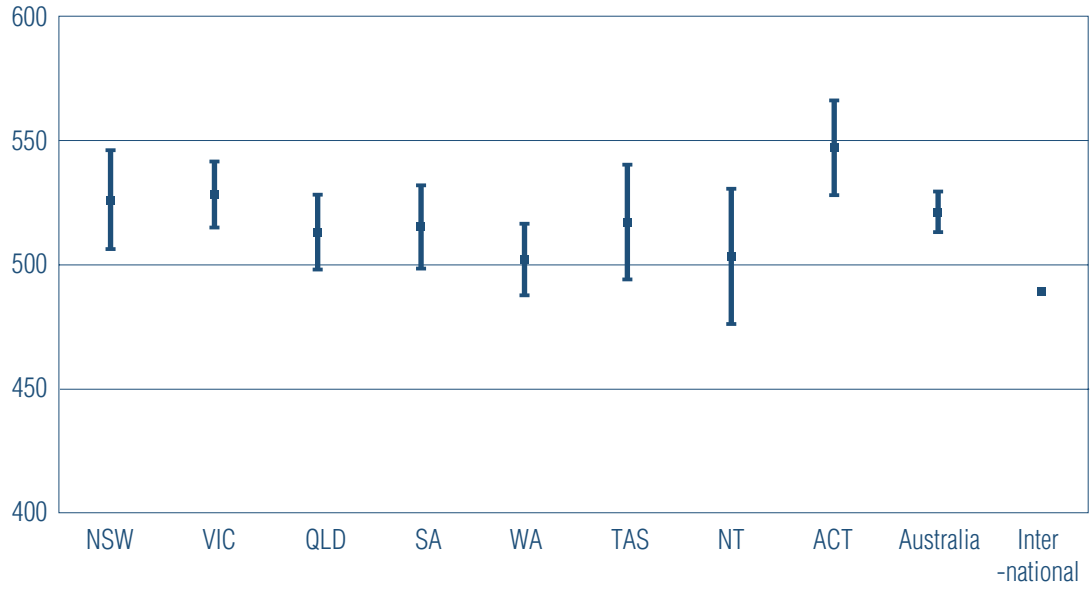


Figure 3.3 Averages and 95% confidence intervals for Year 4 science achievement, by state

Table 3.3 Year 4 science achievement nationally and internationally

All Year 4 TIMSS 2002/03 countries	Average scale score (se)	Average age
Singapore	565 (5.5)	10.3
Chinese Taipei	551 (1.7)	10.2
Australian Capital Territory	547 (9.7)	10.1
Japan	543 (1.5)	10.4
[1]Hong Kong SAR	542 (3.1)	10.2
[1]England	540 (3.6)	10.3
[1]United States of America	536 (2.5)	10.2
Latvia	532 (2.5)	11.1
Hungary	530 (3.0)	10.5
Victoria	528 (6.8)	10.1
New South Wales	526 (10.1)	10.0
Russian Federation	526 (5.2)	10.6
[1]Netherlands	525 (2.0)	10.2
[1]Australia	521 (4.2)	9.9
New Zealand	520 (2.5)	10.0
Belgium (Flemish)	518 (1. 8)	10.0
Tasmania	517(11.6)	10.2
Italy	516 (3.8)	9.8
South Australia	515 (8.5)	9.9
Queensland	513 (7.7)	9.4
[1]Lithuania	512 (2.6)	10.9
Northern Territory	503 (13.8)	9.8
Western Australia	502 (7.3)	9.4
[1]Scotland	502 (2.9)	9.7
Moldova, Rep. of	496 (4.6)	11.0
Slovenia	490 (2.5)	9.8
International average	*489 (0.9)*	*10.3*
Cyprus	480 (2.4)	9.9
Norway	466 (2.6)	9.8
Armenia	437 (4.3)	10.9
Iran, Islamic Rep. of	414 (4.1)	10.4
Philippines	332 (9.4)	10.8
Tunisia	314 (5.7)	10.4
Morocco	304 (6.7)	11.0

[1] These countries did not meet all the sampling requirements

Achievement at the international benchmarks – Year 4

Figure 3.4 shows the proportion of students in each state reaching each of the international science benchmarks, along with the proportions for the highest scoring country, Singapore, and the overall international proportions for comparison. Nationally, students in the Australian Capital Territory did the best at achieving both the highest and the lowest international benchmarks. Around 15 per cent of students in the Australian Capital Territory reached the advanced international benchmark, more than half reached the high international benchmark, and 96 per cent achieved the low international benchmark. The next best achieving states were New South Wales and Victoria, in which around one in ten met the advanced international benchmark, four in ten reached the high international benchmark, and more than 90 per cent achieved the low benchmark. South Australia, Tasmania and Queensland form a group, each with 7 per cent of students achieving the advanced benchmark and around 90 per cent achieving the low benchmark. Not achieving quite so well were students in the Northern Territory and Western Australia. In both states approximately five per cent of students achieved the advanced international benchmark, in the NT more than one-third and in Western Australia around three in ten achieved the high benchmark. However in the Northern Territory in particular, 15 per cent of students failed to reach

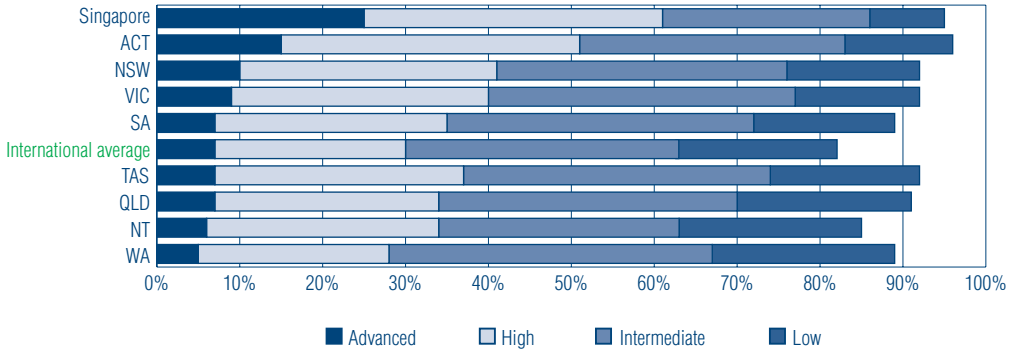


Figure 3.4 Proportion of Year 4 students meeting the international benchmark in science, by state

the lowest benchmark, and even in South Australia and Western Australia the proportions are somewhat worrying, at 11 per cent for both states.

Although lower than the international average, the large 'tail' of students failing to reach the lowest benchmark is a concern. All states, other than the Australian Capital Territory, need to pay particular attention to this issue.

State results – Year 8

Table 3.4 provides the average achievement for each state for Year 8 science, showing also the adjusted multiple comparisons of achievement and the significance of the results. Figure 3.5 illustrates averages and confidence intervals for Year 8 achievement in science for students in each state, and provides, for comparison, the confidence interval for Australia and also the international confidence interval.

As with Year 4 there more similarities than differences between the states in science achievement at Year 8. The only two significant differences were: scores for students in New South Wales were significantly higher than those for Victoria and the Northern Territory; and scores for students in the Australian Capital Territory were also significantly higher than those for students in the Northern Territory.

In comparison to TIMSS 1994/95, this represents a small change. When making comparisons with that study, it is important that comparisons are made with the Year 8 cohort only, as presented in Table A.11 of the TIMSS Australia population 2 report (Lokan et al., 1996). In that comparison, students in the Australian Capital Territory and Western Australia had the strongest outcomes, with those in the Australian Capital Territory outperforming those in all states other than Western Australia and New South Wales, and those in Western Australia outperforming those in Victoria, Tasmania and the Northern Territory.

Figure 3.5 shows that the achievement levels of students in most states is significantly higher than the international average. The only exception to this is the Northern Territory, where there is no significant difference between the average for the state and the international average.

Table 3.5 shows where achievement for each state fitted into the international picture of Year 8 achievement in science. Again, the confidence

Table 3.4 Year 8 science achievement by state

State	Average	se	NSW	ACT	WA	SA	VIC	QLD	TAS	NT
New South Wales	547	9.6		•	•	•	▲	•	•	▲
Australian Capital Territory	538	9.2	•		•	•	•	•	•	▲
South Australia	524	10.9	•	•		•	•	•	•	•
Western Australia	520	6.9	•	•	•		•	•	•	•
Victoria	516	5.3	▼	•	•	•		•	•	•
Queensland	516	6.0	•	•	•	•	•		•	•
Tasmania	504	11.7	•	•	•	•	•	•		•
Northern Territory	482	13.7	▼	▼	•	•	•	•	•	

▲ score significantly higher than that for comparison state
• score not significantly different than that of the comparison state
▼ score significantly lower than that for comparison state
Note: Read **across** the row to compare a state's performance with the performance of each state as listed in the column headings

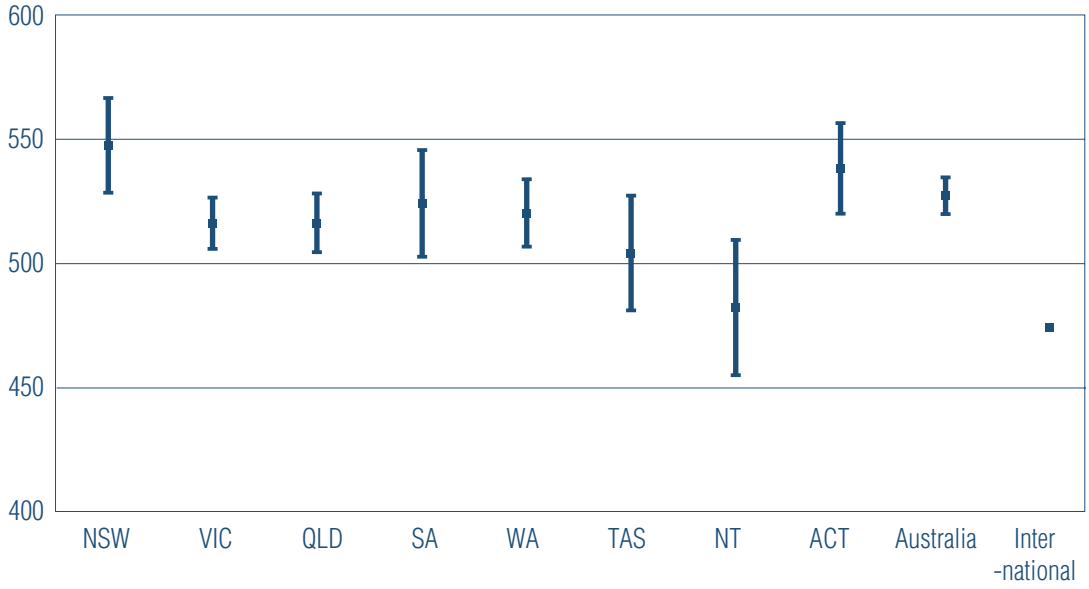


Figure 3.5 Averages and 95% confidence intervals for Year 8 science achievement, by state

intervals associated with the Australian states are larger than those for the country averages because of the smaller number of schools in the state samples. As there are a great many more countries participating at Year 8 level, ability groupings are more apparent in these data than in the Year 4 data.

Students in the highest achieving state, New South Wales, performed at an equivalent level to students in Chinese Taipei: not quite that of Singaporean students, but very close. In the same group were Korea, Hong Kong SAR, Estonia, Japan and England. Students in the Australian Capital Territory also performed at a very high level; equivalent to students as high up in the table as Korea.

The group of states around the Australian average (South Australia, Western Australia, Queensland and Victoria) had similar achievement levels as students in the United States of America, New Zealand, and Sweden.

The achievement of students in Tasmania was significantly higher than the international average, and similar to that of students in Scotland and Malaysia. Students in the Northern Territory, while having the lowest achievement in Australia, still scored at around the international average.

In comparison to science achievement nationally and internationally with TIMSS 1994/95, several differences are evident. New South Wales performed better than in TIMSS 1994/95, and its ranking has moved from around the middle of the distribution to near the top of it. The achievement by students in the Australian Capital Territory has remained fairly high, although achievement in countries such as Japan and Korea has improved to the extent that they now outperform the Australian Capital Territory, instead of being about the same level as they were in TIMSS 1994/95.

Achievement at the international benchmarks – Year 8

Figure 3.6 shows the proportion of students in each state reaching each of the Year 8 international science benchmarks, along with the proportions for Australia as a whole, and for the highest scoring country, Singapore, for comparison. At the Year 8 level, students in New South Wales continued their strong performance from Year 4, with the highest proportion achieving the advanced international benchmark, while students in the Australian Capital Territory again had the greatest proportion of students reaching at least the lowest international benchmark.

Around 15 per cent of students in New South Wales reached the advanced international benchmark, a further 38 per cent reached the high benchmark, and 95 per cent overall reached the low international benchmark. The proportion of South Australian students reaching each of the benchmarks was substantially higher in Year 8 than Year 4, with 10 per cent of Year 8 students reaching the advanced benchmark, and just under 95 per cent reaching the low international benchmark.

Table 3.5 Year 8 science achievement nationally and internationally

All Year 8 TIMSS 2002/03 countries	Average scale score (se)	Average age
Singapore	578 (4.3)	14.3
Chinese Taipei	571 (3.5)	14.2
[1]Korea, Rep. of	558 (1.6)	14.6
[1]Hong Kong SAR	556 (3.0)	14.4
Estonia	552 (2.5)	15.2
Japan	552 (1.7)	14.4
England	550 (4.3)	14.3
New South Wales	547 (9.6)	14.0
Hungary	543 (2.8)	14.5
Australian Capital Territory	538 (9.2)	14.1
[1]Netherlands	536 (3.1)	14.3
[1]United States of America	527 (3.1)	14.2
Australia	527 (3.8)	13.9
South Australia	524 (10.9)	13.8
Sweden	524 (2.7)	14.9
Western Australia	520 (6.9)	13.4
Slovenia	520 (1.8)	13.8
New Zealand	520 (5.0)	14.1
[1]Lithuania	519 (2.1)	14.9
Slovak Republic	517 (3.2)	14.3
Queensland	516 (6.0)	13.4
Victoria	516 (5.3)	14.1
Belgium (Flemish)	516 (2.5)	14.1
Russian Federation	514 (3.7)	14.2
Latvia	512 (2.6)	15.0
[1]Scotland	512 (3.4)	13.7
Malaysia	510 (3.7)	14.3
Tasmania	504 (11.7)	14.2
Norway	494 (2.2)	13.8
Italy	491 (3.1)	13.9
[1]Israel	488 (3.1)	14.0
Northern Territory	482(13.7)	13.8
Bulgaria	479 (5.2)	14.9
Jordan	475 (3.8)	13.9
International average	*474 (0.6)*	*14.5*
Moldova, Rep. of	472 (3.4)	14.9
Romania	470 (4.9)	15.0
[1]Serbia and Montenegro	468 (2.5)	14.9
Armenia	461 (3.5)	14.9
Iran, Islamic Rep. of	453 (2.3)	14.4
[1]Macedonia, Rep. of	449 (3.6)	14.6
Cyprus	441 (2.0)	13.8
Bahrain	438 (1.8)	14.1
Palestinian Nat'l Auth.	435 (3.2)	14.1
Egypt	421 (3.9)	14.4
[1]Indonesia	420 (4.1)	14.5
Chile	413 (2.9)	14.2
Tunisia	404 (2.1)	14.8
Saudi Arabia	398 (4.0)	14.1
[1]Morocco	394 (3.3)	15.2
Lebanon	393 (4.3)	14.6
Philippines	377 (5.8)	14.8
Botswana	365 (2.8)	15.1
Ghana	255 (5.9)	15.5
South Africa	244 (6.7)	15.1

[1] These countries did not meet all the sampling requirements

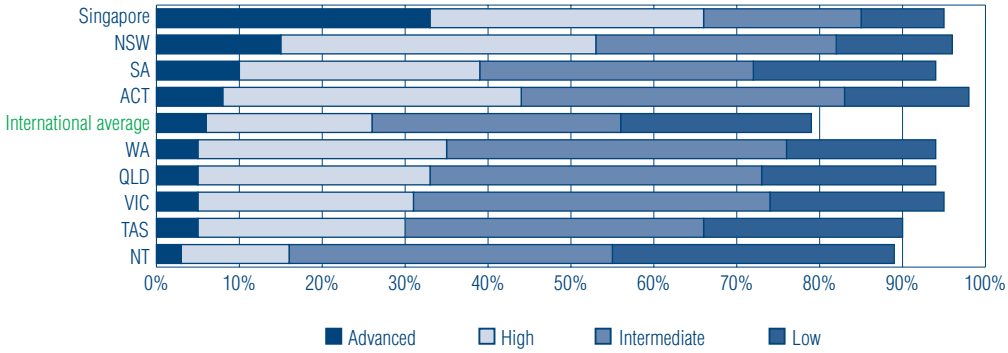


Figure 3.6 Proportion of Year 8 students meeting the international benchmark in science, by state

The position of the Australian Capital Territory in Figure 3.6 is of interest, as their average achievement level in science is second highest of the Australian states at Year 8. The data on benchmarks indicate that the Australian capital Territory education system is achieving good outcomes in science education for the largest percentage of Year 8 students in Australia. Eight per cent of students in the Australian Capital Territory attained the advanced international benchmark, while 98 per cent achieved the low benchmark.

For three of the remaining five states (Western Australia, Queensland and Victoria), the proportion of students achieving the highest and lowest benchmarks is approximately the same. About one in twenty students reached the advanced international benchmark, and about one in twenty failed to achieve the low international benchmark.

Tasmania and the Northern Territory, though, have twice (or more, in the case of the Northern Territory) the proportion of students failing to achieve the low benchmark as achieved the advanced benchmark. Even if the proportion achieving the highest benchmark was higher this would still be problematic, but the Northern Territory only achieved three per cent at the advanced benchmark, and only 16 per cent achieved the high international benchmark.

At Year 8, as at Year 4, the 'tail' should be of concern to educators. The TIMSS 2002/03 data indicate that while there is ample room at the advanced end of the achievement distribution for growth, there is also considerable need for improvement of Australia's achievement at the other end of the scale: improving the proportions of students achieving the lowest international benchmark, which is a very basic standard.

Summary

This chapter has examined Australian students' achievements in the science content areas of *life science*, *chemistry*, *physics*, *earth science* and *environmental science*. At Year 4, *chemistry* and *physics* are combined into *physical sciences*, and *environmental science* was not assessed. At both year levels, Australian students performed significantly above the international average in all science content areas.

While there were no gender differences in Year 4 in the overall science scores, females significantly outperformed males in *life science*. At Year 8, males significantly outperformed females in *chemistry*, *physics*, *earth science* and *environmental science*.

There were very few differences in science achievement between the states at either year level. Placing the states in an international context, all states performed at or significantly above the international average at both year levels, and the performance of Year 4 students in the Australian Capital Territory was not significantly different than that of students in Singapore or Chinese Taipei, the highest ranking countries in the world. Students in Year 8 in the highest achieving state, New South Wales, performed at an equivalent level to students in Chinese Taipei: not quite as high as students in Singapore, but very close.

Nationally, students in Year 4 in the Australian Capital Territory did the best at achieving both the highest and the lowest international benchmarks, and in Year 8 had the greatest proportion of students achieving the lowest benchmark. Students in New South Wales also performed strongly at both year levels. The proportion of Australian students, particularly in Tasmania and the Northern Territory, who do not reach the lowest benchmark, is of concern to educators and policy makers. While there is ample room at the advanced end of the achievement distribution for growth, a priority should be improving the proportion of students achieving at the lowest benchmark.

The next chapter, Chapter 4, utilises the information gathered from the student questionnaires to describe the Australian student population at both year levels, and to explore the relationships between these characteristics and science achievement.

Chapter 4
Australian TIMSS students

Chapter 4
Australian TIMSS students

Past IEA studies have found that student achievement is related to student characteristics (Beaton, Martin, Mullis, Gonzalez, Smith, and Kelly, 1996; Martin et al., 2000). In TIMSS 2002/03 students completed a 30-minute questionnaire as well as the test booklet. This chapter utilises the information gathered from this questionnaire to describe the Australian student population at both Year 4 and 8 and explore the relationship between some of these characteristics and science achievement.

The questionnaire asked students about their home background, their self-confidence and attitudes towards learning mathematics and science, activities within mathematics and science lessons, their use of computers, their attitudes towards school, feelings of safety at school, activities outside school, extra tutoring in mathematics and science and the amount of homework given in mathematics and science. Year 8 students were also asked about their educational aspirations. Unless otherwise specified, the data given in this chapter are weighted[1], allowing inferences to be made about the Australian Year 4 and Year 8 student populations.

Student background characteristics

Gender and age

As Table 4.1 shows, there were virtually the same proportion of females and males who participated in TIMSS 2002/03. The distribution varies across states, but none of the differences in number of males and females are significant. Gender was only weakly related to science achievement at Year 8 (a correlation of 0.17), with males scoring higher than females at Year 8 (as was seen in Chapter 2). Gender was not related at all to science achievement at Year 4 (a correlation of 0).

Table 1.1 illustrated that the average age of students in Year 4 and 8 varied from state to state, with Queensland and Western Australia having the youngest students. Overall the average age of Australian Year 4 students was 9.9 years and that of Australian Year 8 students 13.9 years. Interestingly, for both year levels, age is not related to science achievement (correlations of 0.09 at Year 4 and 0.02 at Year 8). Therefore, any differences in achievement between the states are unlikely to be due to differences in the average age of students.

Table 4.1 Percentage of females and males in TIMSS 2002/03 by state

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Year 4									
Females	50	50	51	49	52	54	54	47	50
Males	50	50	49	51	48	46	46	53	50
Sample N	837	617	678	546	609	453	227	294	4261
Year 8									
Females	52	50	54	47	50	50	53	54	51
Males	48	50	46	53	50	50	47	46	49
Sample N	800	774	771	633	641	551	264	346	4780

[1] Students included in the final TIMSS samples are not equally representative of the entire student population of a country, despite random sampling of schools and classes. Survey weights are thus incorporated into the analysis in order to provide accurate population estimates.

Parents' education and home education resources

Students, at Year 8 only, were asked to indicate the highest level of education attained by their parents. The levels ranged from finishing primary school to post-graduate education. As evidenced by the high proportion of students ticking "I don't know", this is a difficult question for students to answer, which is why it was not asked of Year 4 students (internationally, 17 countries had response rates of 85% or less on these questions). Table 4.2 shows that, in Australia, 16 per cent of fathers and 20 per cent of mothers did not complete secondary school. This is less than the proportion of Australian parents who did not complete secondary schooling in TIMSS 1998/99 (almost a quarter of mothers and a fifth of fathers, Zammit, Routitisky & Greenwood, 2002) and less again than the 40 per cent of mothers and 34 per cent of fathers in 1994/95 (Lokan, et al., 1996). However, responses of "I don't know" were not included in TIMSS 1994/95 as a valid response category, which has inflated the percentages of the other categories in comparison to the percentages in TIMSS 1998/99 and 2002/03.

The combined parents' education variable, which uses the highest level of education attained by either parent, is related to science achievement in Australia (a correlation of 0.23). Figure 4.1 shows the average science achievement and confidence intervals for Year 8 students at each level of parents' education[2]. Figure 4.1 shows that Australian students with parents who attained higher levels of education had higher science achievement scores than those with parents who reached lower levels of education (although there is no difference in achievement between students with parents whose highest education is either lower secondary or upper secondary school). Internationally, higher levels of parents' education were associated with higher levels of student achievement in most countries. This is also reflected in the international average, where students with university educated parents scored more than 90 points higher than students with parents with only primary schooling.

Past IEA studies have shown a clear relationship between the educational resources available in the home and student achievement (Martin et al., 2000). In TIMSS 1998/99, an index of home educational resources was developed, which combined parents' education, number of books in the home and the presence of study aids (computer, study desk for own use, dictionary) to come up with three categories – high, medium and low. A high level indicated more than 100 books in the home, all three study aids and that either parent's highest level of education was to have finished university or higher. A low level indicated 25 or fewer books in the home, not all three study aids and both parents' highest level of education was some secondary schooling or less. A medium level included all other combinations of responses.

In TIMSS 1998/99 Australia had the second highest percentage of students indicating a high level of home educational resources, with 24 per cent of students in this category and only 3 per cent in the low category (Martin et al., 2000). In TIMSS 2002/03 this index was constructed for Australian students (at Year 8 only). Table 4.3 shows that the number of students in the high category has dropped slightly to 15 per cent but the number of students with a low level of home educational resources is still very low at 2 per cent. The skew towards the high end of this index is due to the high number of students who had all 3 educational aids (96% of Australian Year 8 students had a computer at home, 98% had a dictionary and 92% had their own study desk). Table 4.3 shows that

Table 4.2 Percentage of students by parents' education (Year 8 only)

Education level	Mother	Father
Completed primary school	3	2
Some secondary school	17	14
Completed secondary school or apprenticeship	18	19
TAFE or College diploma	17	14
Bachelor's degree	9	9
Beyond Bachelor's degree	5	8
I don't know	33	35

[2] As this is a scale which is derived from a combination of the mother's and father's educational level, the categories are slightly broader than those given in the student's responses shown in Table 4.2.

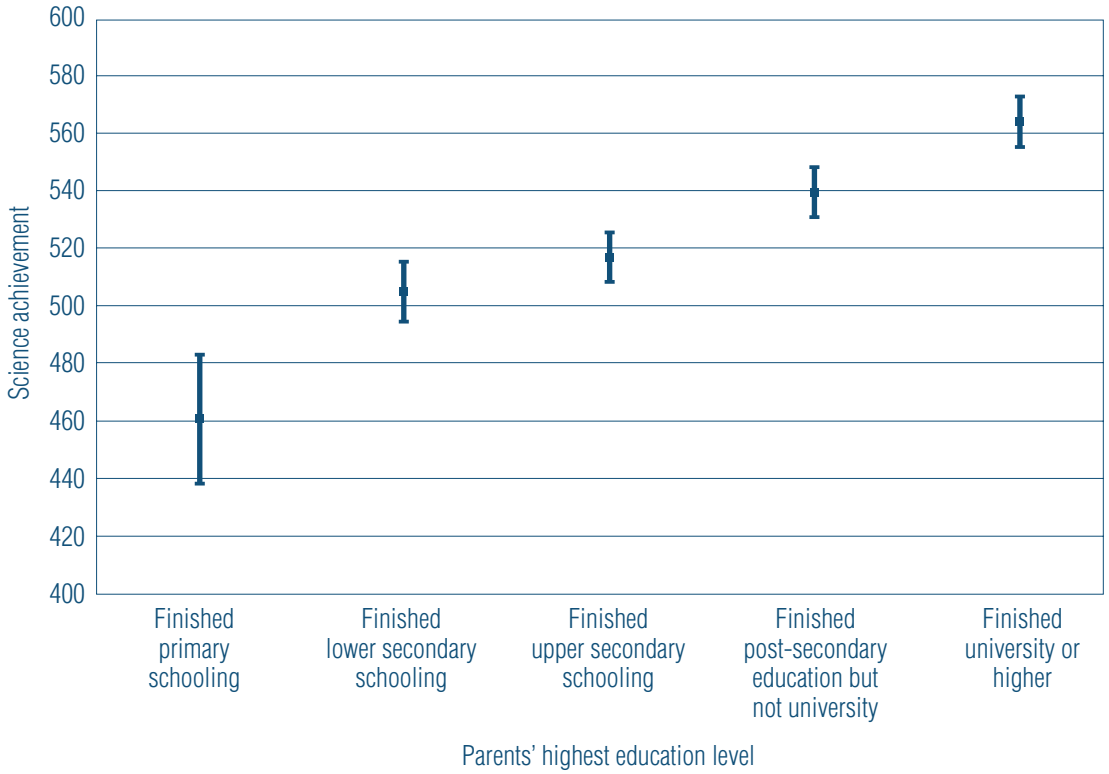


Figure 4.1 Year 8 science achievement by the highest education level of either parent

science achievement is related to educational resources in the home (a correlation of 0.29), with students in the high category having higher science achievement than those in the medium category and those in the medium category scoring higher than those in the low category.

The index of home educational resources included parents' education so could not be applied to Year 4. However, the number of books in the home has been used by itself as an indicator of educational capital in the home in the past. In TIMSS 1994/95 and TIMSS 1998/99, there was a clear relationship between the number of books in the home and student achievement in mathematics and science. In both these studies, around 40 per cent of Australian Year 8/9 students had more than 200 books in their home (Lokan, et al., 1996; Lokan, et al., 1997; Zammit, et al., 2002). In TIMSS 2002/03, 31 per cent of Australian Year 8 students had more than 200 books in the home, exceeded or equalled only by Hungary (31%), Sweden (32%) and Estonia (45%). At Year 4, Australia had the highest proportion (23%) of students with more than 200 books in the home. At both year levels, just over one-fifth of students had between 101 and 200 books, about a third had 26 to 100 books, just over 10 per cent had 11 to 25 books and about five per cent had less than 10 books in the home.

Figures 4.2 and 4.3 show that there is a clear relationship between the number of books in the home and science achievement for Australian students. At Year 4 the correlation between the number of books in the home and science achievement is 0.27, at Year 8 the correlation is 0.3. The difference in science between students with more than 200 books and those with 10 or less books in the home was 78 score points at Year 4 and 89 score points at Year 8. Internationally, the difference was 68 points at Year 8 (from 506 to 438) and 65 points at Year 4 (from 518 to 453).

Table 4.3 Index of home education resources – percentage of Year 8 students and achievement by category[3]

	Low	Medium	High
Percent of Year 8 students	2	83	15
Science achievement	438 (10.7)	523 (3.8)	572 (4.4)

[3] Standard errors appear in parentheses.

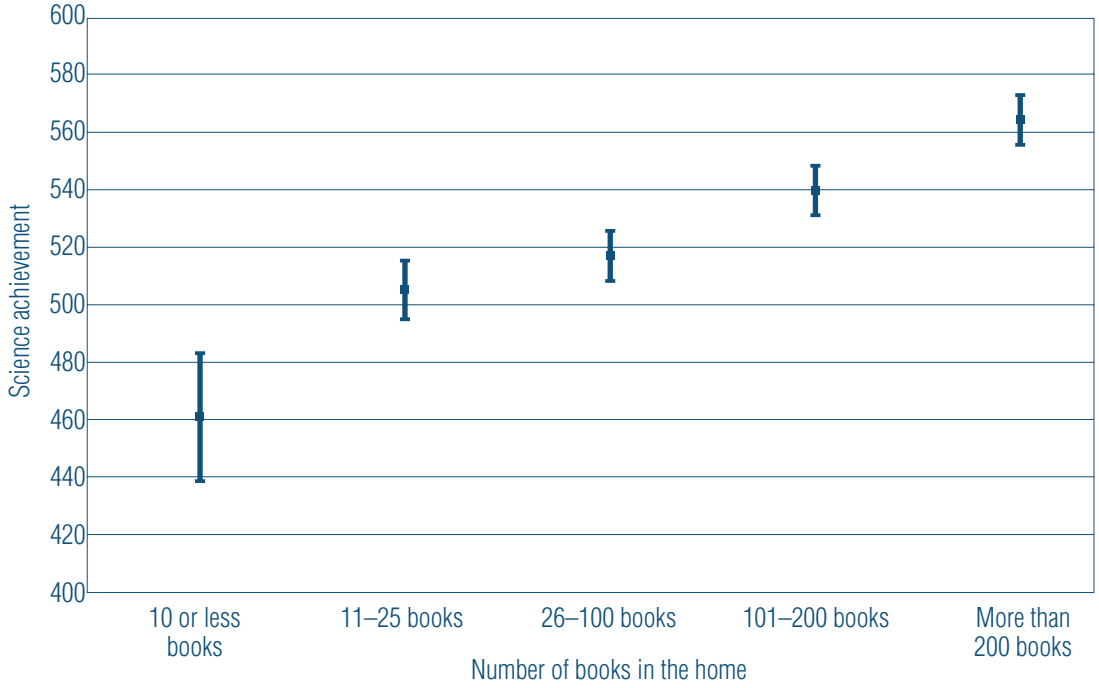


Figure 4.2 Year 4 science achievement by the number of books in the home

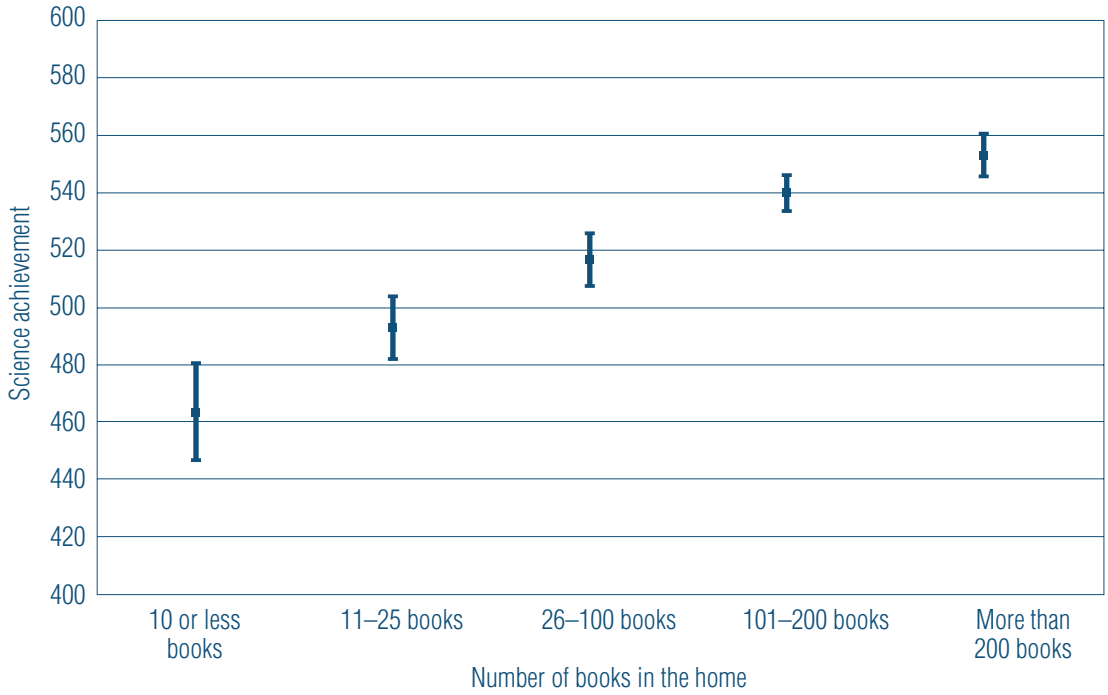


Figure 4.3 Year 8 science achievement by the number of books in the home

Indigenous students

Table 4.4 shows the proportion of Indigenous students in the Australian TIMSS sample. Overall, five per cent of Year 4 students are Indigenous. This is similar to the proportion of Year 4 students the Australian Bureau of Statistics (ABS) reported in 2002 (4.2%). The proportion of Year 8 students who indicated that they were of Aboriginal or Torres Strait Islander background in TIMSS

Table 4.4 Percentage of Indigenous students in the TIMSS sample

	Year 4	Year 8
Australia	5	3

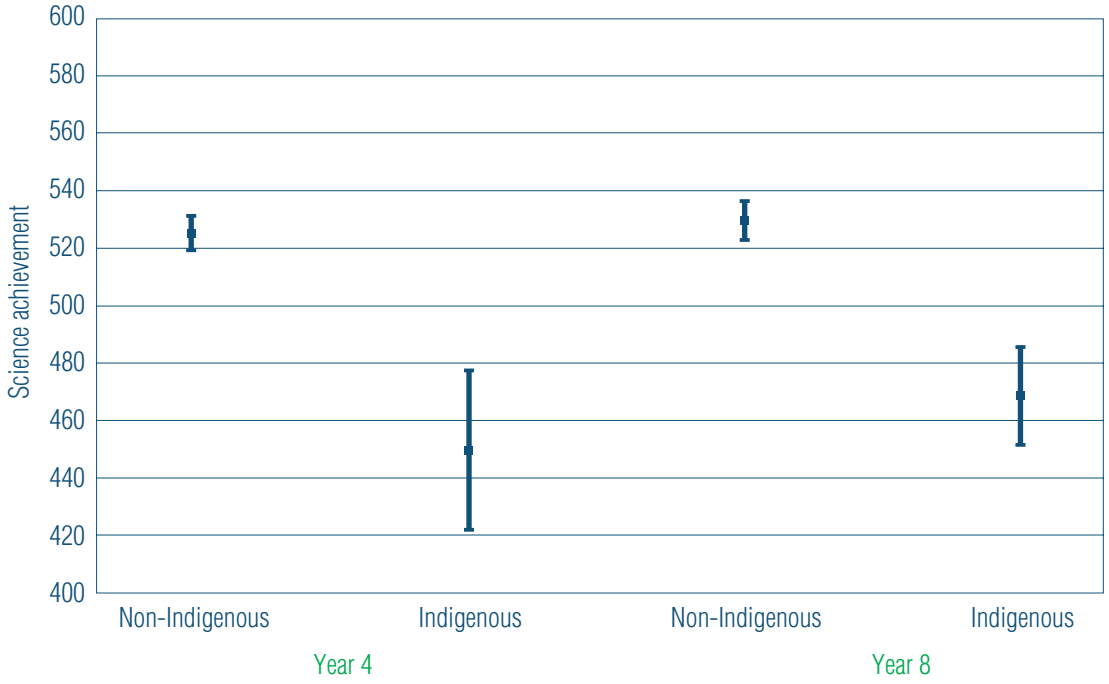


Figure 4.4 Year 4 and Year 8 science achievement for Indigenous and non-Indigenous Australian students[4]

2002/03 was three per cent, about the same as the proportion (3.6%) reported by the ABS (2003).

Figure 4.4 shows clearly that Indigenous students are not performing as well as non-Indigenous Australian students in science at either Year 4 or Year 8. At Year 4, Indigenous students achieved an average score of 450, 76 score points less than the average score of non-Indigenous students (526). At Year 8, Indigenous students achieved an average score of 469, 61 score points less than the average score of non-Indigenous students (530). However, at both year levels, when compared to the international data, Australian Indigenous students' average science score is not significantly different from the international average.

Has the science achievement of Indigenous students improved since TIMSS 1994/95?

The performance of Australia's Indigenous students in core subject areas continues to be an issue. The difference in scores between Indigenous students and all Australian students, provides us with an idea of the magnitude of such differences in science. At Year 4, the difference in TIMSS 1994/95 between Indigenous students and all Australian students was a little more than 0.6 of a

Table 4.5 Percentage of students and their parents by place of birth

	Australia	Other English	Southern Europe	Other Europe	Asia	Middle East and North Africa	Other Africa	Central and South America	Pacific Islands
Year 4									
Students	91	4	1	1	2	1	0	0	0
Mothers	70	10	3	3	9	2	1	0	2
Fathers	67	11	5	3	8	3	1	1	2
Year 8									
Students	88	4	1	1	6	1	0	0	1
Mothers	66	11	3	3	12	2	1	1	2
Fathers	64	11	5	4	11	3	1	1	1

[4] While the Year 4 and Year 8 scores have been presented here on the same axes for the sake of expedience, the Year 4 and Year 8 tests were not scaled together and, therefore, are not comparable. That is, a score of 500 for a Year 4 student does not mean that they have the same mathematical skills as a Year 8 student who also scores 500. This holds for all Year 4 and Year 8 achievement data.

Table 4.6 Percentage of students and parents born in English speaking countries, including Australia, by state

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Year 4									
Students	94	96	96	96	94	99	97	96	95
Mothers	75	79	89	86	80	95	85	81	80
Fathers	73	76	84	86	81	95	86	78	78
Both parents	68	72	82	81	74	88	80	72	74
Neither parent	20	16	8	9	13	6	9	12	15
Year 8									
Students	87	92	94	95	95	98	95	94	92
Mothers	66	74	87	87	87	95	83	81	77
Fathers	63	73	87	82	84	94	84	85	75
Both parents	60	67	82	78	79	91	76	77	70
Neither parent	31	20	9	10	8	2	9	11	19

standard deviation (62 score points) in TIMSS 1994/95, while in TIMSS 2002/03 the situation had worsened slightly, with a difference of almost three-quarters of a standard deviation (71 score points). For Year 8 students, the situation was more encouraging. In TIMSS 1994/95, the difference was 0.83 of a standard deviation (83 score points), while in 2002/03 it was a substantially lower 0.58 of a standard deviation (58 score points). It is quite possible that either or both of these changes are statistically significant, and this will be investigated in a further report which will examine the achievement of Indigenous Australians in more detail.

Country of birth and language background

Table 4.5 categorises the place of birth of Australian students and their parents. Around 90 per cent of students were born in Australia (91% at Year 4 and 88% at Year 8). Of those students who were not born in Australia, or whose parents were not born in Australia, most come from English-speaking countries or Asia.

As Table 4.6 shows, the majority of Year 4 and Year 8 students come from English-speaking backgrounds, with only 15 per cent of Year 4 students and 19 per cent of Year 8 students having neither parent born in an English-speaking country. Correspondingly, at both year levels, just over 90 per cent of students speak English at home always or almost always (see Table 4.7). Of the states, Tasmania had the highest proportion of students with an English speaking background with 99 per cent of Year 4 students and 98 per cent of Year 8 students from English speaking countries and 96 per cent of Year 4 students and 98 per cent of Year 8 students speaking English at home always or almost always. Of the other states, New South Wales has the greatest proportion of students coming from non-English speaking backgrounds.

Internationally, in most countries the majority of students spoke the language of the test at home always or almost always – overall 81 per cent of Year 4 students and 79 per cent of Year 8 students spoke the language of the test at home always or almost always. Most of the countries that had a large percentage of students who did not speak the language of the test at home frequently were countries that had relatively low performance. However, Singapore (the country that scored the highest in science) had only 46 per cent of Year 4 students and 42 per cent of Year 8 students who spoke the language of the test at home always or almost always.

Internationally, across countries, students at both year levels who always or almost always spoke the language of the test at home achieved a higher score than those that spoke it less frequently. However, in Australia, the relationship is not so clear-cut. For Year 4 students, those who always or almost always spoke English at home had an average score of 525, whereas those who spoke English less frequently had an average score of 492

Table 4.7 Percentage of students speaking English at home (always or almost always) by state

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Year 4	89	90	94	92	92	96	88	93	91
Year 8	86	91	96	95	97	98	95	95	92

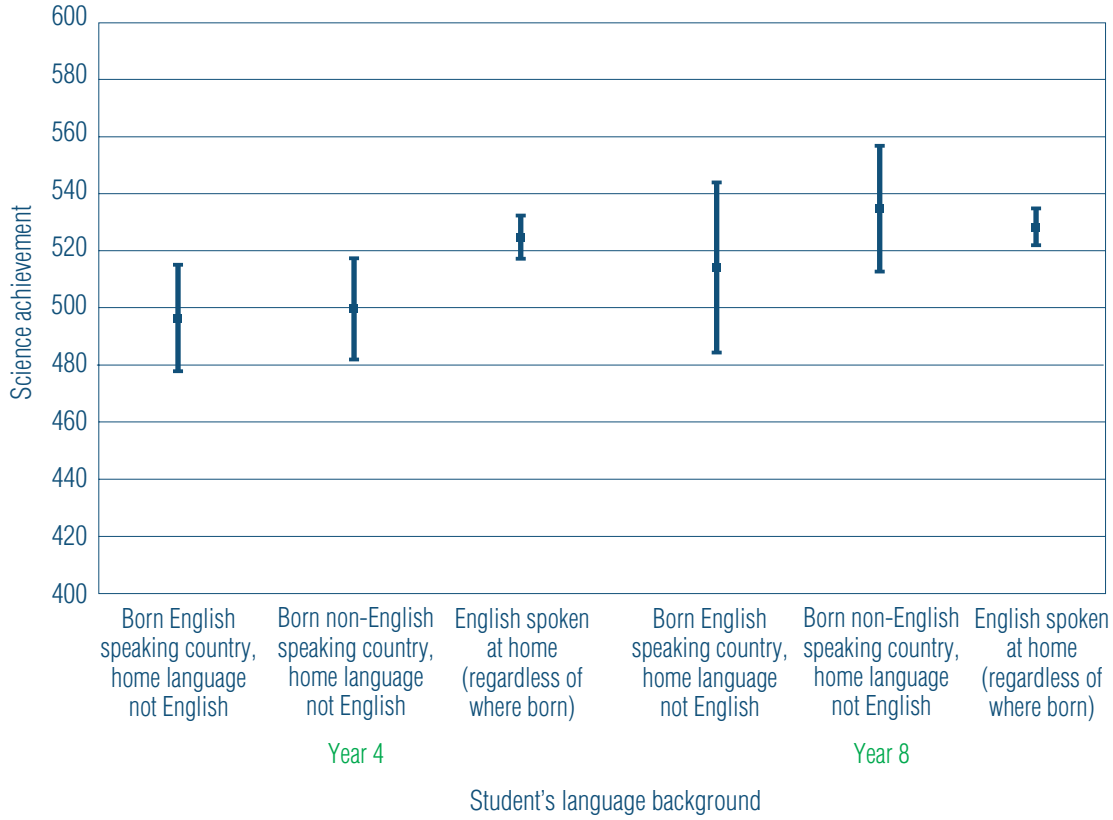


Figure 4.5 Year 4 and Year 8 science achievement by student's language background

(a correlation of 0.12). However, Year 8 students who always or almost always spoke English at home had an average score of 529, higher but not significantly different to those who spoke English less frequently, who had an average score of 520 (a correlation of 0.03).

In TIMSS 1994/95, for Australia, country of birth and language spoken at home were combined to give 4 categories of students – those born in an English speaking country but did not speak English at home; those born in an non-English speaking country and did not speak English at home; those born in an English speaking country and spoke English at home; and those born in a non-English speaking country and spoke English at home (in Years 8 and 9 these last two categories were combined). It was found that for students in Years 4 and 5 and also Years 8 and 9, science achievement increased fairly uniformly from the first category to the last category (Lokan, et al., 1996; Lokan, et al., 1997). In TIMSS 2002/03 this line of enquiry was replicated. However, the same results were not found. As Figure 4.5 shows, Year 4 students who spoke English at home had higher science achievement than any other category. However, there was little difference between any of the categories for Year 8 students.

Out-of-school activities

Homework

In order to gauge how much time students were required to devote to science homework, two questions were asked: 'How often does your teacher give you homework in science?' and 'When your teacher gives you science homework, about how many minutes are you usually given?' From the responses to these questions an index was constructed that assigned students to a high, medium or low level of required time for science homework. Students in the high category reported that they were assigned more than 30 minutes of science homework at least 3–4 times per week. Students in the low category reported being assigned not more than 30 minutes of science homework twice a week. The middle category included all other response combinations.

The percentage of students falling into each category and the average science achievement for students in that category was calculated for all countries. The international average for students in Year 4 was six per cent in the high category, 33 per cent in the medium category and 61 per cent in the low category. The Philippines had the most

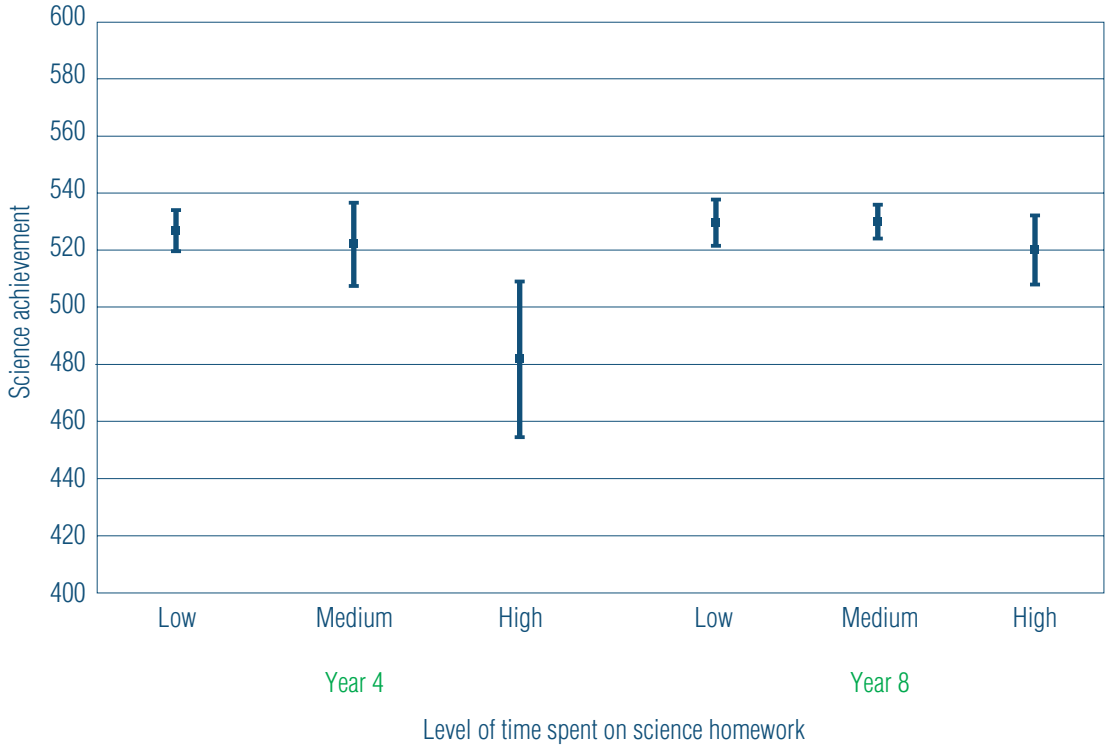


Figure 4.6 Year 4 and Year 8 science achievement by level of time spent on science homework

students, 16 per cent, at the high level, and Japan and the Netherlands had only one per cent of students reporting high amounts of science homework. At Year 4, students in the high category had the lowest average science achievement. This may be because lower-achieving students may be assigned more homework than higher achieving students as a remedial strategy.

In most countries, Year 8 students reported being given more science homework than Year 4 students. The international average for students studying General/Integrated Science in Year 8 was 13 per cent at the high level, 44 per cent at the medium level and 43 per cent at the low level. Students in the high category had lower science achievement than students in the medium and low categories. Of those countries that taught science as a single subject, Ghana had the highest number of students in the high category – 25 per cent. Japan, Scotland and Korea all had less than five per cent of students falling into the high category. Across countries, the number of students assigned high amounts of science homework does not seem to be related to science achievement. Korea was in the top five scoring countries yet had only four per cent of students reporting high levels of homework while Singapore, the top scoring country, had 18 per cent of students in the high category of the index.

Australian students received relatively low amounts of homework. At Year 4 Australia was in the bottom seven countries in terms of numbers of students reporting receiving high amounts of homework. Only two per cent of Year 4 students fell into the high category, 20 per cent reported a medium amount and 78 per cent reported receiving a low amount of science homework. Nine per cent of Year 8 students reported high amounts of science homework, 35 per cent reported a medium amount and 56 per cent reported a low amount. Figure 4.6 shows the relationship between science homework and science achievement. At both Years 4 and 8, there was not a linear relationship between the amount of science homework received and science achievement (correlations of 0), although at Year 4 students reporting receiving high levels of homework did have lower average achievement than students in the other categories.

Students were also asked how much time they spent on a normal school day doing homework (all subjects, not just science). The majority (56%) of

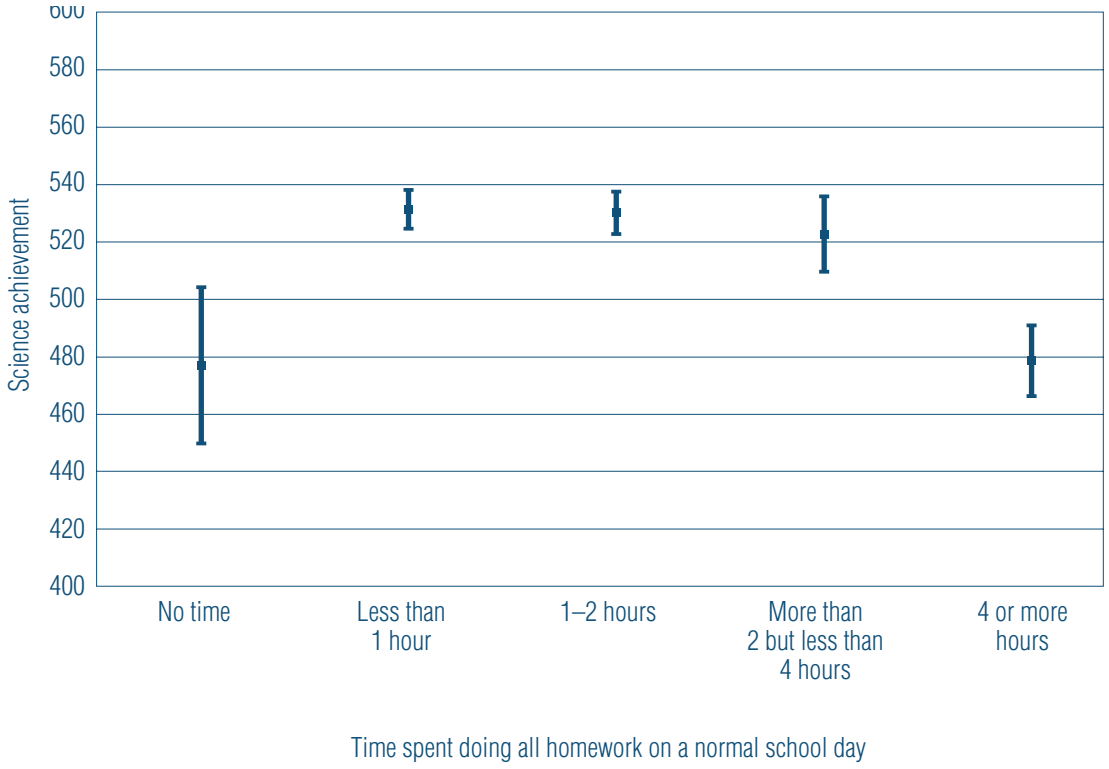


Figure 4.7 Year 4 science achievement by amount of time spent on all homework

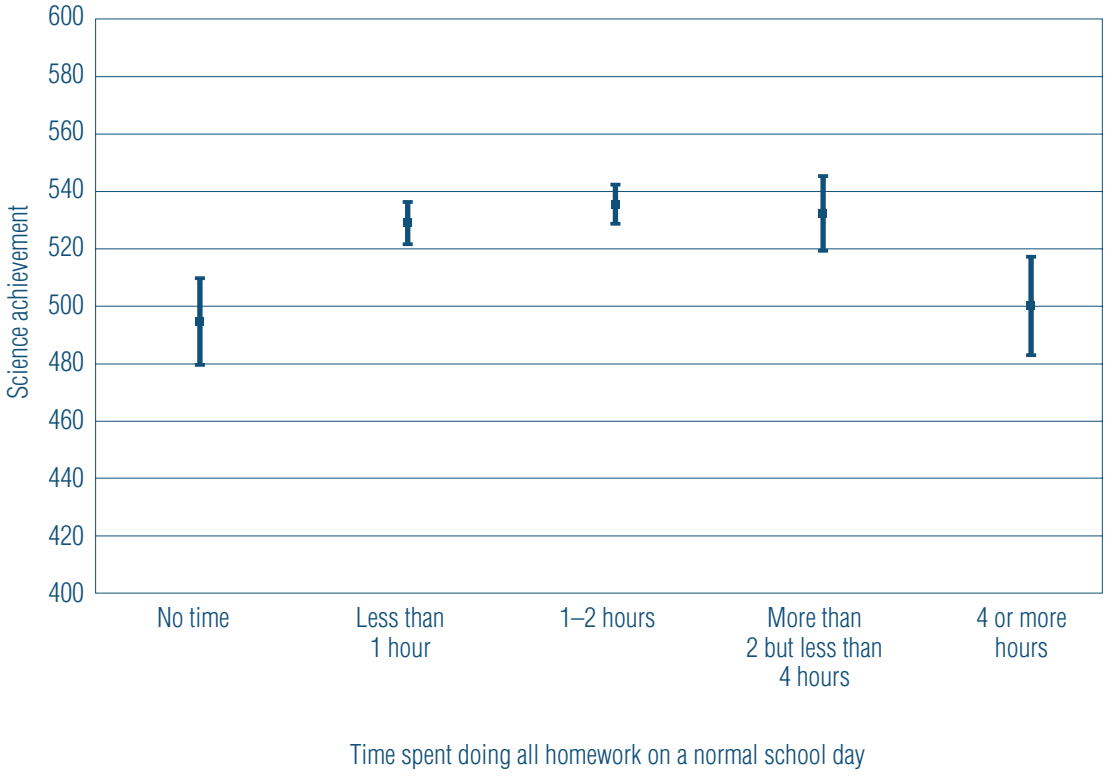


Figure 4.8 Year 8 science achievement by amount of time spent on all homework

Australian Year 4 students did some but less than one hour of homework on a normal school day, while another 24 per cent did between one and two hours. The remaining 20 per cent were spread equally between the categories of 'no time', 'between two and four hours' and 'more than four hours'. The amount of homework Year 8 students do on a normal school day is slightly higher than that of Year 4 students – 40 per cent did up to an hour, another 40 per cent did one to two hours, 10 per cent did two to four hours and three per cent did over 4 hours of homework on a school day. While there does not appear to be a relationship between science homework and science achievement for Australian students, Figures 4.7 and 4.8 show that students at both year levels that do some homework in any subject, but less than 4 hours a day, have better science achievement than those that do none or those that do more than 4 hours. What cannot be concluded from this data is the direction of the relationship. The ready conclusion to be made is that some homework, but not too much, is beneficial to achievement in science. However, it could also be said that those students who aren't achieving as well either do no homework because they are disengaged from schooling or do more than average amounts of homework because they are assigned more in order to 'catch-up'.

Questions about time spent on homework were also asked of students in TIMSS 1994/95 and TIMSS 1998/99 (Lokan, et al., 1996; Lokan, et al., 1997; Zammit, et al., 2002). However, the questions asked and the measures derived from these questions were not exactly the same as those asked in TIMSS 2002/03 and hence are not directly comparable. However, the general trend, for students who do some but not a lot of homework in any subject, to have higher scores on the science achievement scale, was also found in these prior TIMSS studies.

Leisure activities

Students were also asked about how much time they spend, on a normal school day, on leisure activities such as reading for enjoyment or sport. Internationally the two most popular activities were watching television or videos and playing or talking with friends – on average, Year 4 students spend a bit less than two hours on each of these activities and Year 8 students spend about two hours. In Australia, these were also among the most popular activities, along with sport. Year 4 students spend, on average, just under two hours on each of these three activities, whereas Year 8 students spend, on average, two hours on watching television and closer to an hour and a half on playing sport and playing or talking with friends.

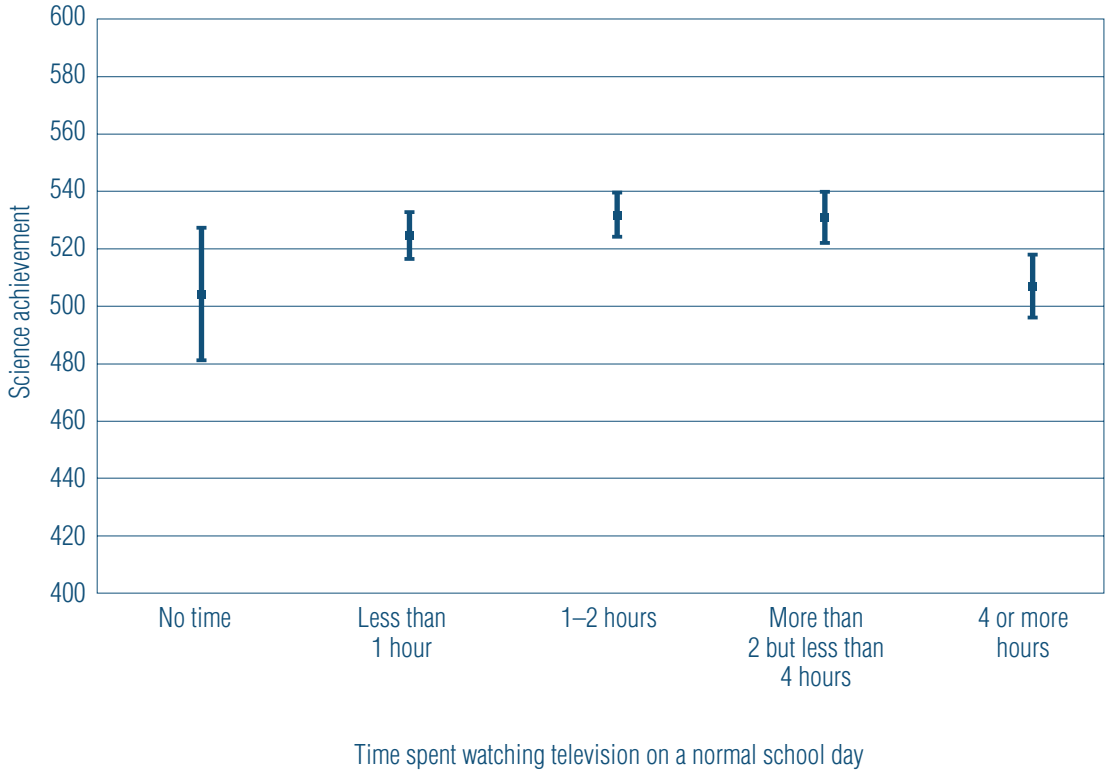


Figure 4.9 Year 4 science achievement by amount of time spent watching television

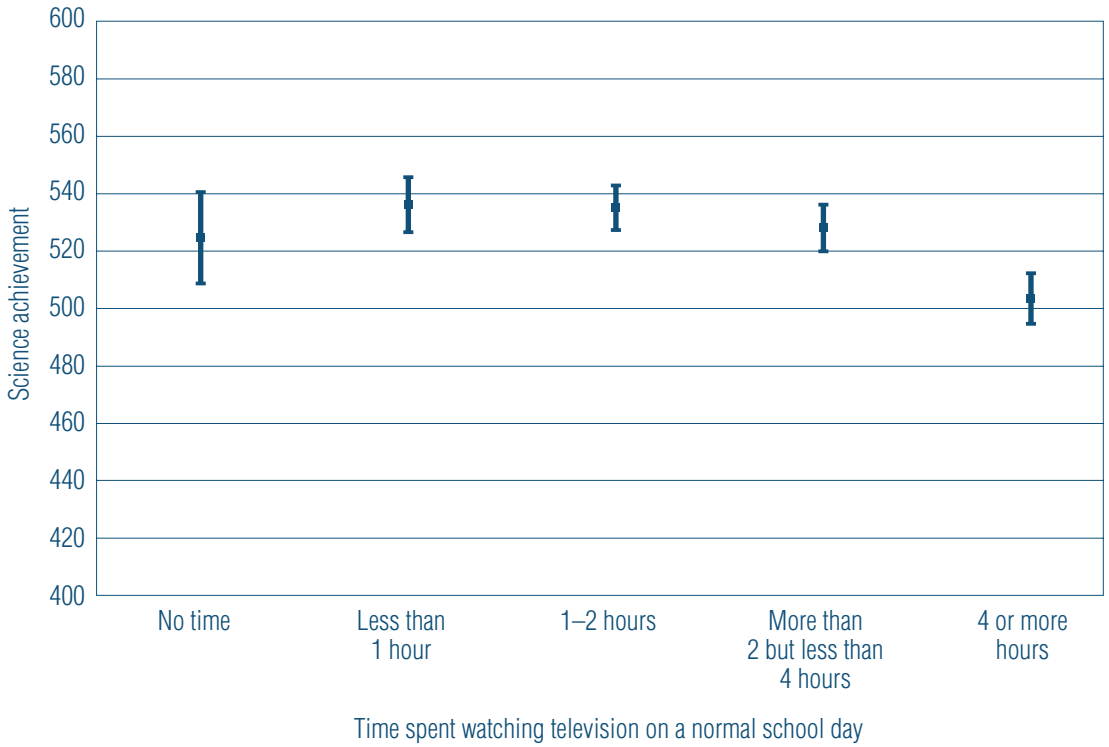


Figure 4.10 Year 8 science achievement by amount of time spent watching television

Figures 4.9 and 4.10 show the relationship between time spent watching television and science achievement. As in previous TIMSS studies (Lokan, et al., 1996; Lokan, et al., 1997; Zammit, et al., 2002), about two thirds of Australian Year 4 and Year 8 students watched some television but less than 2 hours on a normal school day. Slightly more Year 8 students than Year 4 students watch more than 2 hours of television a day (39% compared to 33%). The relationship between time spent watching television and science achievement is also similar to previous years. That is, students who watched more than 4 hours of television a day had significantly lower levels of science achievement than students who watched less television.

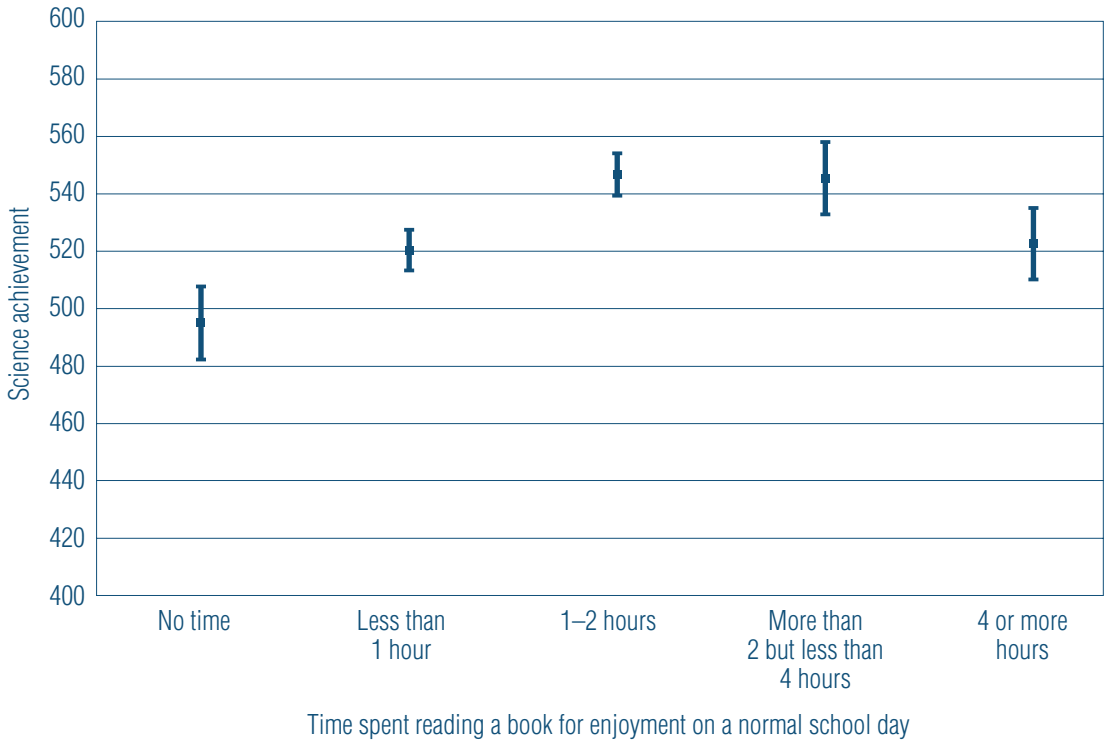


Figure 4.11 Year 4 science achievement by amount of time spent reading for enjoyment

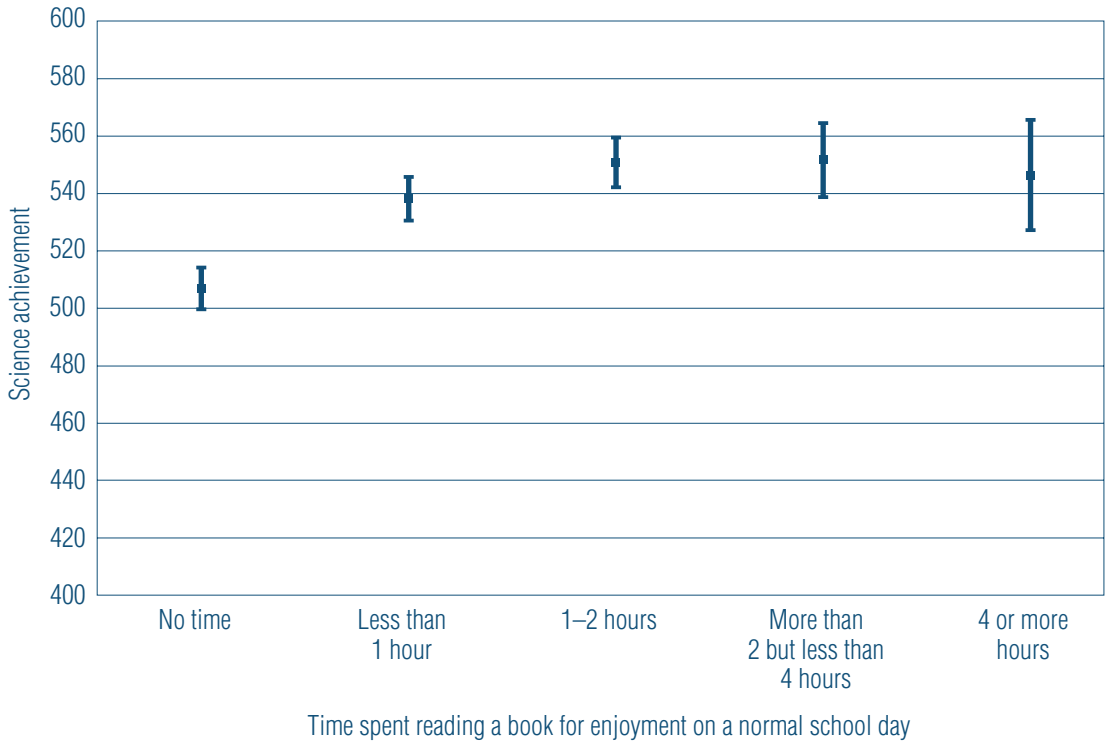


Figure 4.12 Year 8 science achievement by amount of time spent reading for enjoyment

Figures 4.11 and 4.12 show the relationship between time spent reading for enjoyment and science achievement. Australian Year 4 students were more inclined than Year 8 students to spend some time reading for enjoyment on a normal school day – two thirds of Year 4 students spent up to 2 hours on a normal school day reading for enjoyment, compared to half of Year 8 students. As for the Australian Year 8 and 9 students in TIMSS 1998/99, 40 per cent of Year 8 students did not read for enjoyment at all (Zammit, et al., 2002). Like in previous TIMSS studies (Lokan, et al., 1996; Lokan, et al., 1997; Zammit, et al., 2002), there was a weak positive relationship (a correlation of 0.15 at Year 4 and 0.22 at Year 8) between reading for enjoyment and science achievement – in both Years 4 and 8, students that read for between one and four hours a day had a higher average science achievement score than those that did not read at all.

Use of computers

Australia had one of the highest percentages of students with a computer at home. At Year 4, 92 per cent of students had a computer at home (the United States of America and the Netherlands being the only other countries to have the same or a higher percentage of students with a computer at home). At Year 8, 96 per cent of students had a computer at home (Norway, Hong Kong SAR, Korea, Sweden and the Netherlands being the only other countries to have the same or a higher percentage of students with a computer at home). Interestingly, Australia is one of the few countries that actually had more Year 4 and Year 8 students reporting that they have a computer at home than have a study desk or table for their use. The other countries reporting this phenomenon are the other English speaking countries - the United States of America, New Zealand, England and Scotland – and Hong Kong SAR (for both Year 4 and Year 8), Singapore (at Year 8), and Chinese Taipei and Italy (at Year 4).

As Table 4.8 shows, there is some variation between states as to the number of students who have a computer at home. Year 4 students in the Northern Territory are the least likely to have a computer at home, at only 84 per cent. In comparison, almost all students in the ACT have a computer at home.

Table 4.8 Percentage of students who have a computer at home by state

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Year 4	92	94	91	90	93	90	84	97	92
Year 8	97	97	94	94	93	91	91	99	96

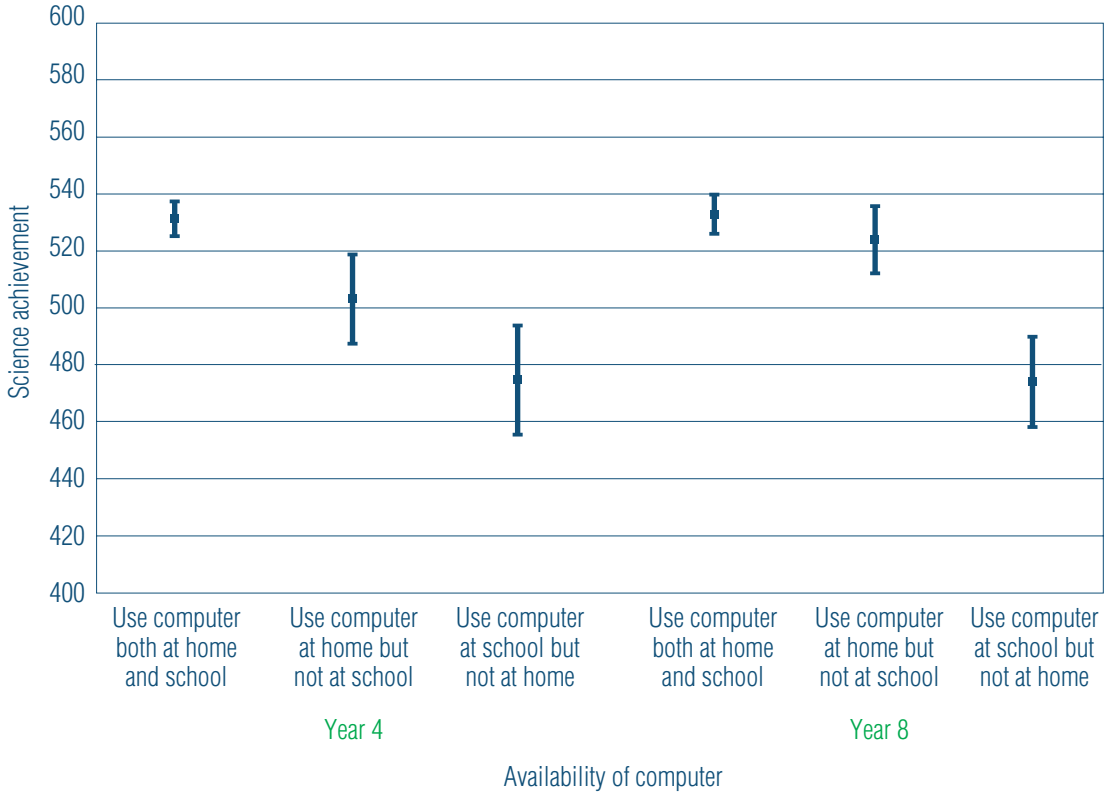


Figure 4.13 Year 4 and Year 8 science achievement by the availability of computers

In Australia, 98 per cent of students (at both Year 4 and 8) use a computer at either school or home. Of those students, 80 per cent of Year 4 and 83 per cent of Year 8 students use a computer at both home and school. In comparison, the international average is that 43 per cent of Year 4 students and 39 per cent of Year 8 students use a computer at both home and school. Hong Kong SAR, England and Chinese Taipei also had more than 80 per cent of Year 8 students using computers at home and school. At Year 4 the only other country was Chinese Taipei.

In Australia, the availability of computers is related to science achievement at both Year 4 and 8, although in slightly different ways, as can be seen in Figure 4.13 (a correlation of 0.23 at Year 4 and 0.17 at Year 8). At Year 4, students who used computers both at home and at school had a higher average science achievement than those that used computers only at home or only at school (the numbers of students who didn't use computers at all or only used them elsewhere are too small for a sensible comparison of achievement). This pattern was also present at the international level, especially at Year 8. However, in Australia, Year 8 students who used computers both at home and at school had a similar achievement level as those who used computers just at home. Both groups had higher science achievement than those who used computers only at school.

While the availability of computers and the general use of computers were positively related to science achievement, the relationship of specific uses of the computer with science achievement is less clear. Figures 4.14 and 4.15 show the relationship of science achievement and the use of computers to look up ideas and information for science at Years 4 and 8 in Australia. At both year levels it appears that those students that use the computer to look up ideas and information for science a few times a year to once or twice a month have the highest average science achievement. At first glance, this relationship is unexpected. However, it could be hypothesised that those students who have higher science achievement are more targeted in their use of the computer and therefore use the computer in their study of science less frequently than students who do less well in science.

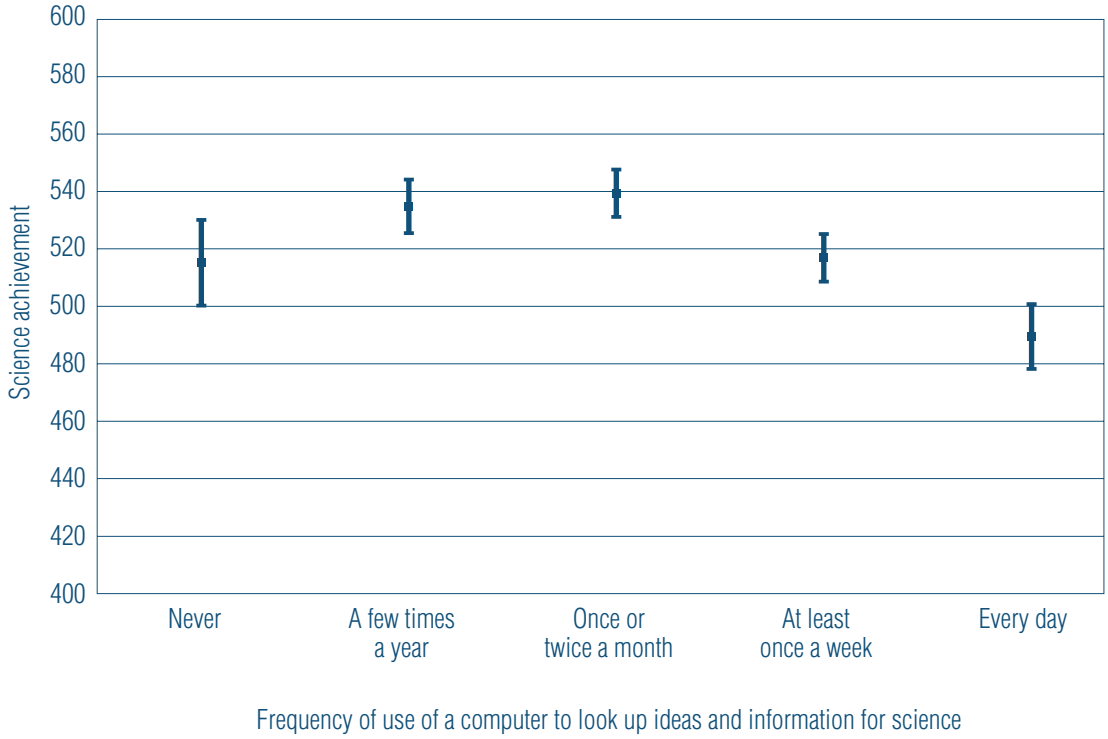


Figure 4.14 Year 4 science achievement by the use of computers to look up ideas and information for science

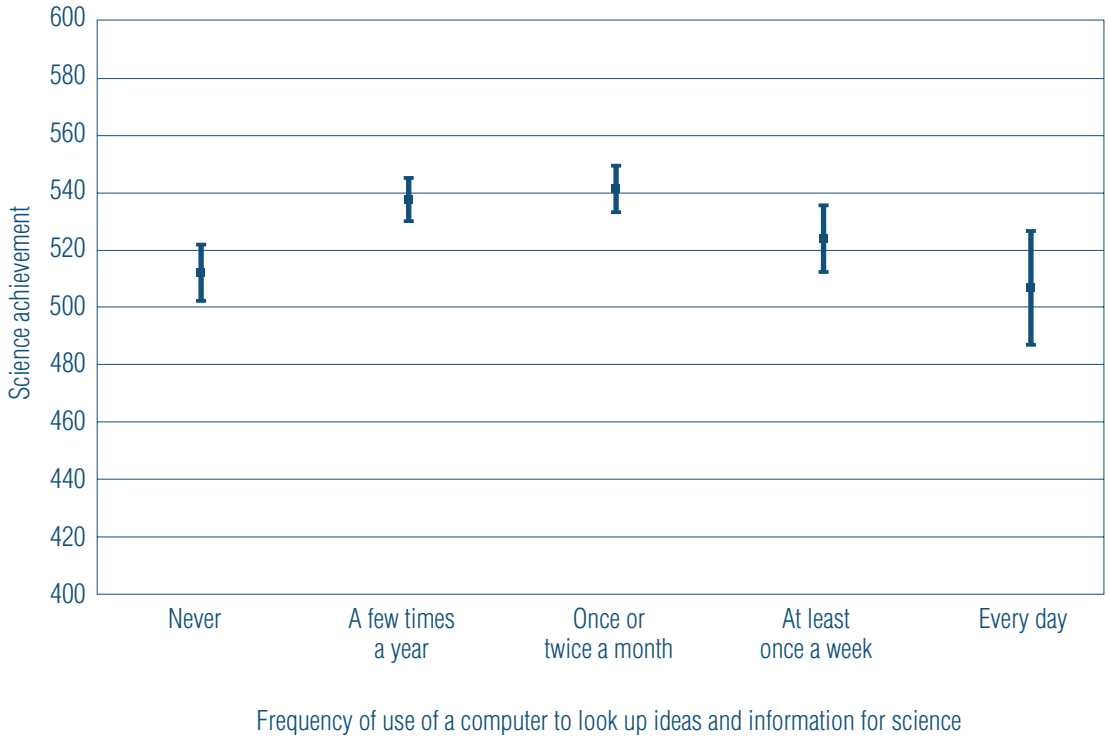


Figure 4.15 Year 8 science achievement by the use of computers to look up ideas and information for science

Attitudes towards learning science

Students were asked a series of questions about how they feel about learning science. These questions were oriented to the students' self-confidence in learning science and also to how the students value science. Those questions that focussed on the future (such as jobs or future study) were only asked of Year 8 students. Table 4.9 lists the statements and their correlation with science achievement for Australian students. This shows that the statements most strongly correlated with science achievement are those about self-confidence in learning science for both year levels. Of the valuing science statements, wanting a job that uses science has the highest correlation with science achievement (Year 8 students only).

Self-confidence in learning science

The four statements about self-confidence in learning science were combined (some having been reversed first) to form an index of students' self-confidence in learning science. Students who agreed a little or agreed a lot with all four statements were assigned to the high level of the index, while students who disagreed a little or disagreed a lot with all four were assigned to the low level. The medium level includes all other possible combinations of responses.

Internationally, 48 per cent of Year 8 students studying integrated science had high self-confidence in learning science. The percentages ranged from 20 per cent in Japan and Korea to 69 per cent in Tunisia. At Year 4, the level of self-confidence is higher than at Year 8, with, on average, 59 per cent of students reporting high self-confidence in learning science. The Year 4 percentages ranged from 32 per cent in Singapore to 78 per cent in Slovenia. Australian students had relatively high self-confidence with 66 per cent of Year 4 students and 49 per cent of Year 8 students at the high level of the index. Interestingly, most of the top five countries in terms of science achievement had relatively low percentages of students with high self-confidence in learning science. As most of these countries are from the Asia-Pacific region, it may be that they share cultural traditions that encourage modest self-confidence.

Figures 4.16 and 4.17 show the percentages of Australian males and females at each level of the index. Interestingly, there are no gender differences in self-confidence in learning science at Year 4. However, at Year 8 there are significantly more males reporting a high level of self-confidence and significantly more females reporting low levels of self-confidence.

While between countries there does not appear to be a clear relationship between self-confidence in learning science and science achievement, within countries and internationally as a whole, a positive relationship is apparent. Figure 4.18 shows the relationship between self-confidence in learning science and science achievement for Australian students. The index of self-confidence in learning science has a clear positive association with science achievement (a correlation of 0.21 at Year 4 and 0.28 at Year 8) – students with high self-confidence in learning science have higher science achievement than students with low self-confidence.

Table 4.9 Correlations of student attitudes with science achievement

Statements about science	Year 4	Year 8
Self-confidence in learning science		
I usually do well in science	0.11	0.28
Science is more difficult/harder for me than for my classmates	–0.23	–0.23
Science is not one of my strengths/I am just not good at science	–0.20	–0.26
I learn things quickly in science	0.13	0.24
Valuing science		
I would like to take/do more science in school	0.01	0.20
I enjoy learning science	0.06	0.19
I think learning science will help me in my daily life	-	0.22
I need science to learn other school subjects	-	0.18
I need to do well in science to get into the post-school course of my choice	-	0.20
I would like a job that involved using science	-	0.26
I need to do well in science to get the job I want	-	0.21

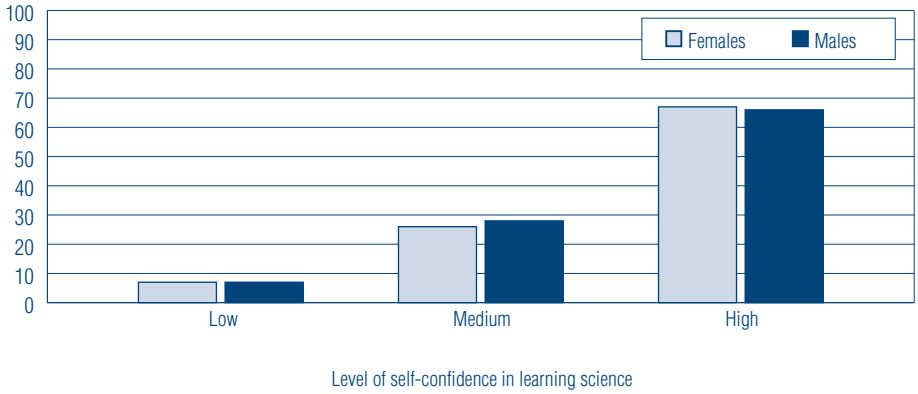


Figure 4.16 Percentage of Year 4 females and males reporting high, medium and low levels of self-confidence in learning science

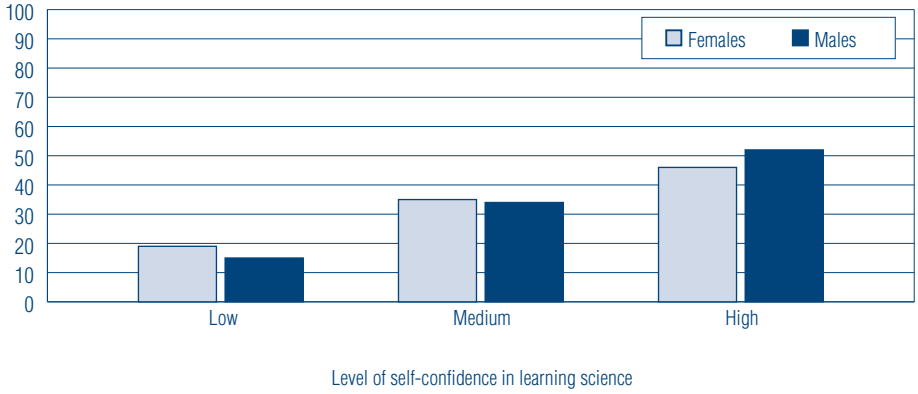


Figure 4.17 Percentage of Year 8 females and males reporting high, medium and low levels of self-confidence in learning science

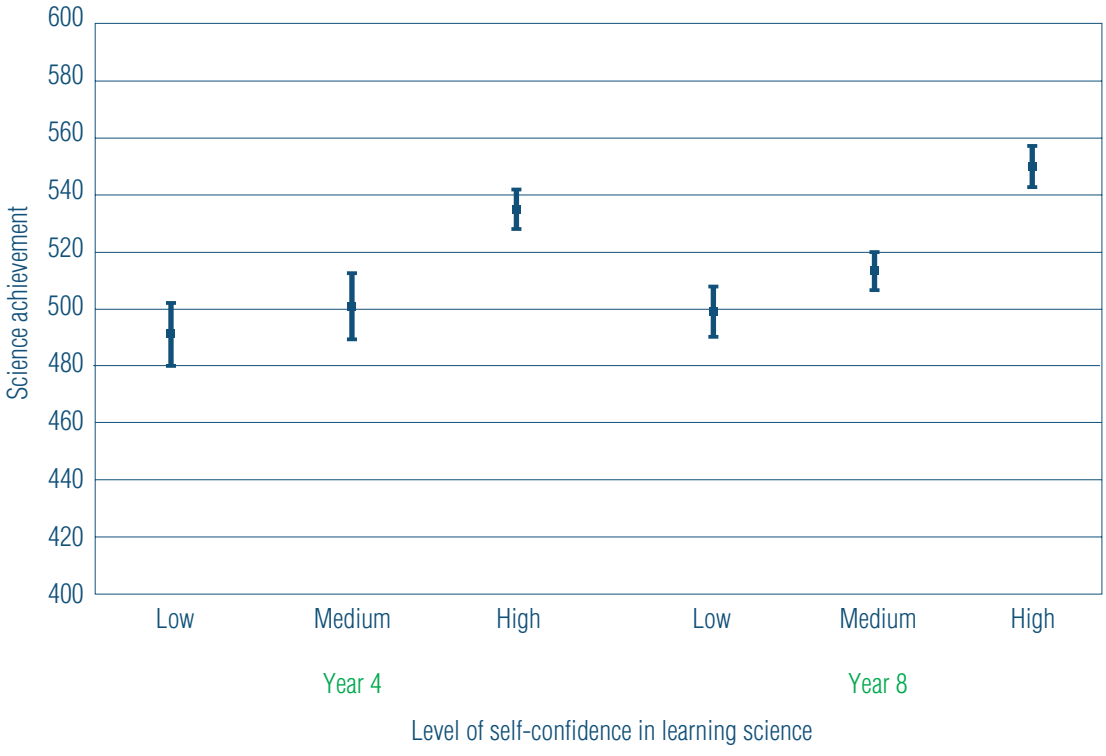


Figure 4.18 Year 4 and Year 8 science achievement by level of self-confidence in learning science

Table 4.10 Enjoyment of learning science – percentage of males and females by response category

I enjoy learning science	Year 4		Year 8	
	Females	Males	Females	Males
Agree a lot	62	65	26	33
Agree a little	25	20	37	39
Disagree	13	15	37	28

Enjoyment of science

The degree to which students enjoy learning science has some association with science achievement (a correlation of 0.06 at Year 4 and 0.19 at Year 8). In Australia, there are more Year 4 students who agree a lot or a little that they enjoy learning science (87%) than Year 8 students who agree a lot or a little (67%). Table 4.10 shows the percentages of females and males giving each response (agree a lot, agree a little, disagree) to the statement 'I enjoy learning science'. There is no difference between females and males at Year 4 in enjoyment of learning science. However, at Year 8, males appear to enjoy learning science more than females.

Internationally, the average percentage of students agreeing a lot that they enjoy learning science has increased since 1994/95, from 44 per cent to 55 per cent at Year 4 and from 23 per cent to 44 per cent for Year 8 integrated science. Australia was one of a small number of countries (including Singapore, New Zealand and the United States of America, amongst others) that showed a significant increase, at both Years 4 and 8, in the percentage of students who agreed a lot that they enjoy learning science. Figures 4.19 and 4.20 show the Australian students' responses to the statement 'I enjoy learning science' in TIMSS 1994/95 and TIMSS 2002/03.

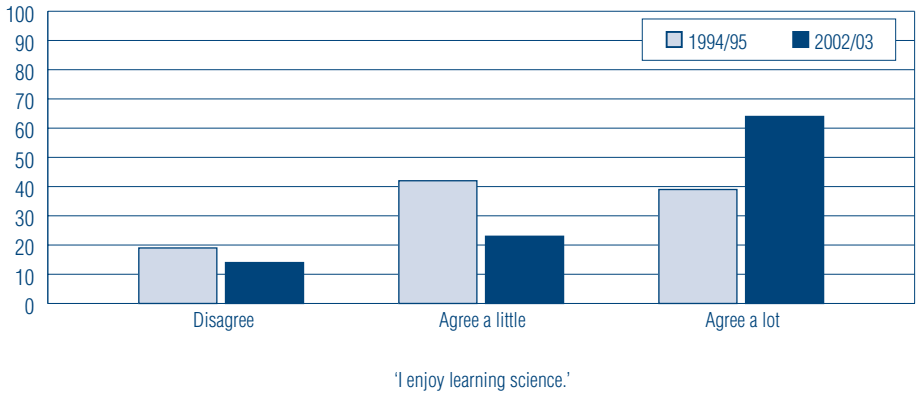


Figure 4.19 Year 4 student responses to 'I enjoy learning science' in 1994/95 and 2002/03

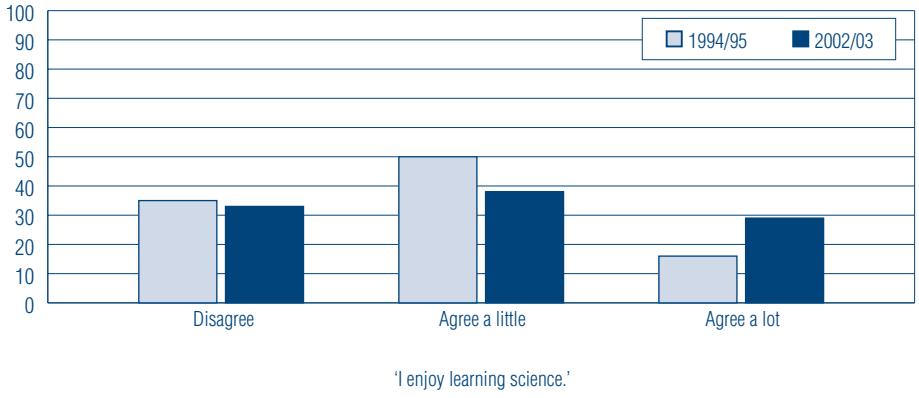


Figure 4.20 Year 8 student responses to 'I enjoy learning science' in 1994/95 and 2002/03

Valuing science

The seven statements about valuing science were combined to form an index of students valuing science for Year 8 students. Students who agreed a little or agreed a lot with all seven statements were assigned to the high level of the index, while students who disagreed a little or disagreed a lot with all seven were assigned to the low level. The medium level includes all other possible combinations of responses.

Internationally, 57 per cent of Year 8 students studying integrated science were in the high category, 31 per cent in the medium category and only 12 per cent in the low category. This suggests that students generally place a high value on science. However, in some countries (Botswana, Egypt, Ghana, Jordan, Tunisia, the Palestinian National Authority and Morocco) 80 per cent or more students place a high value on science, whereas others (Japan and Korea) have fewer than 20 per cent of students in the high category.

Australian Year 8 students don't overwhelmingly value science – 36 per cent put a high value on science, 37 per cent only a medium value and about 27 per cent are in the low category. As Figure 4.21 shows, in Australia, valuing science is positively related to science achievement (a correlation of 0.26). Like the index of self-confidence in learning science, between countries there does not appear to be a clear relationship between valuing science and science achievement. However, within countries and internationally as a whole, a positive relationship is apparent.

Of the statements that make up the index of students valuing science, the statement 'I would like a job that involved using science' had the strongest correlation with achievement for Australian students. Eighteen per cent of Australian Year 8 students agreed a lot that they would like a job that involved using science, 24 per cent agreed a little, 29 per cent disagreed a little and 29 per cent disagreed a lot. Figure 4.22 shows a clear positive relationship between science achievement and students' agreement with the statement 'I would like a job that involved using science'.

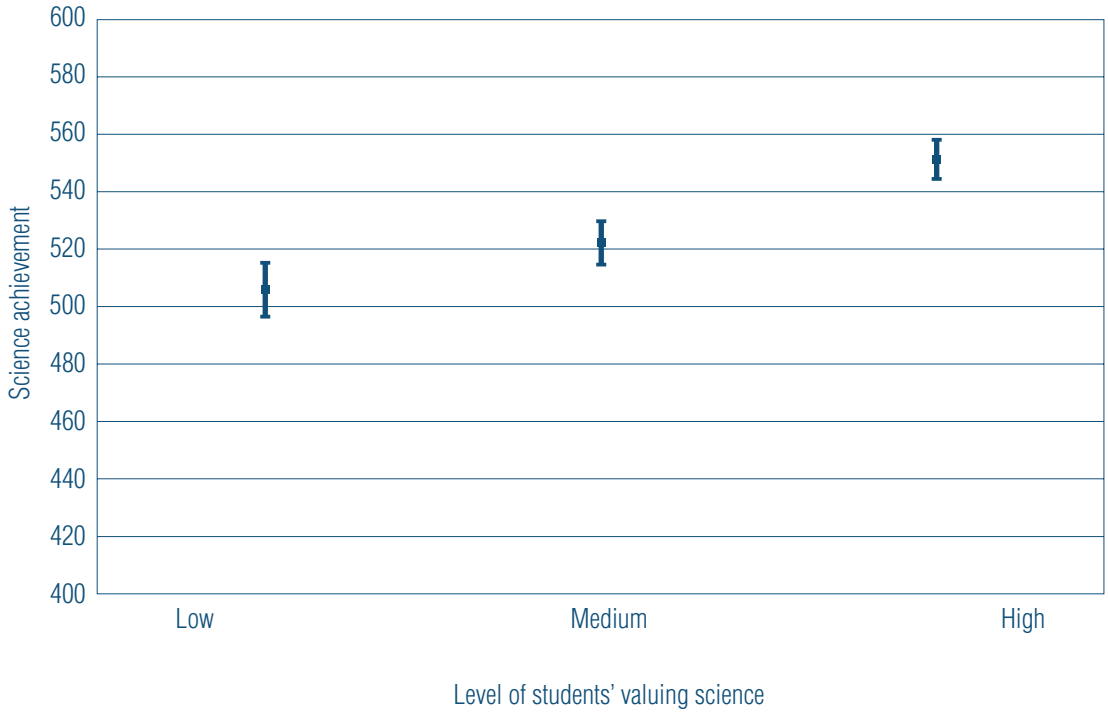


Figure 4.21 Year 8 science achievement by level of students' valuing science

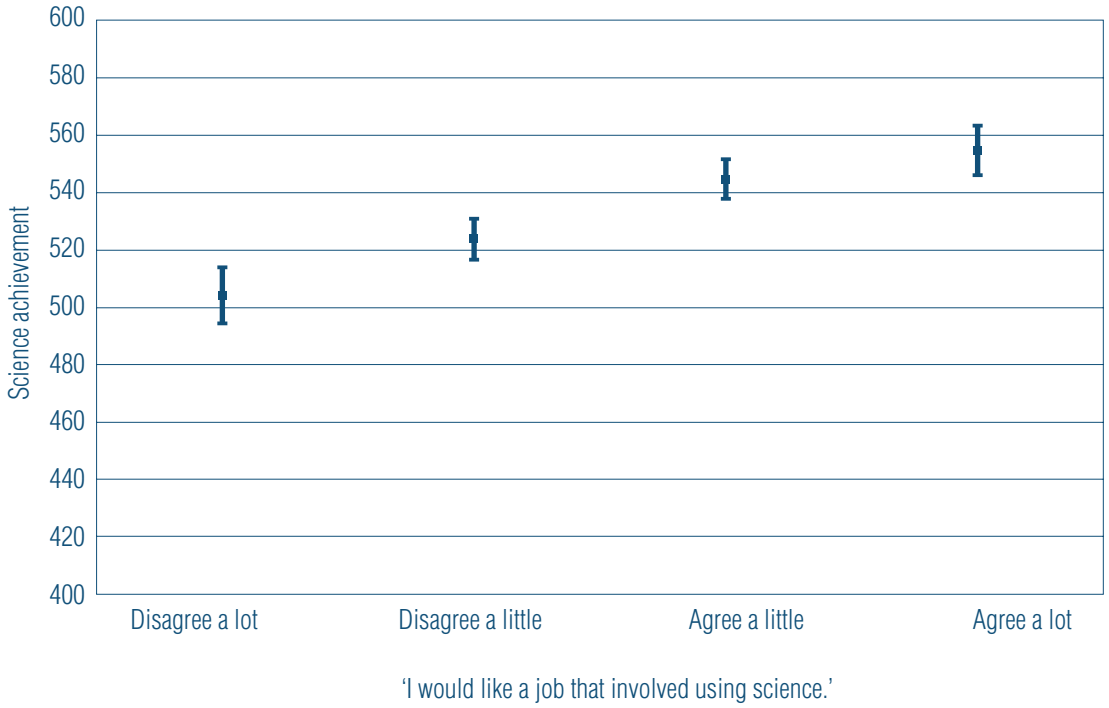


Figure 4.22 Year 8 science achievement by desiring a job that involves using science

Educational aspirations

Students in Year 8 were also asked about how far they expected to go in school and further education. Internationally, 54 per cent of Year 8 students reported that they expected to finish university. This is higher than the expectations of Australian Year 8 students – only about 40 per cent of Australian Year 8 students expect to complete university or higher. Table 4.11 shows the educational aspirations of Year 8 males and females in Australia.

Internationally it was found that those students who expected to finish university had substantially higher average science achievement than those without university expectations. This pattern was also found in Australia. Figure 4.23 shows the positive relationship between educational aspirations and science achievement (a correlation of 0.29) for Australian students.

Table 4.11 Percentage of Year 8 students by educational aspirations and gender

	Not finish secondary school	Finish secondary school or apprenticeship	TAFE or college diploma or certificate	Bachelor's degree	Post-graduate degree	I don't know
Females	2	14	30	21	19	15
Males	4	18	26	15	22	17

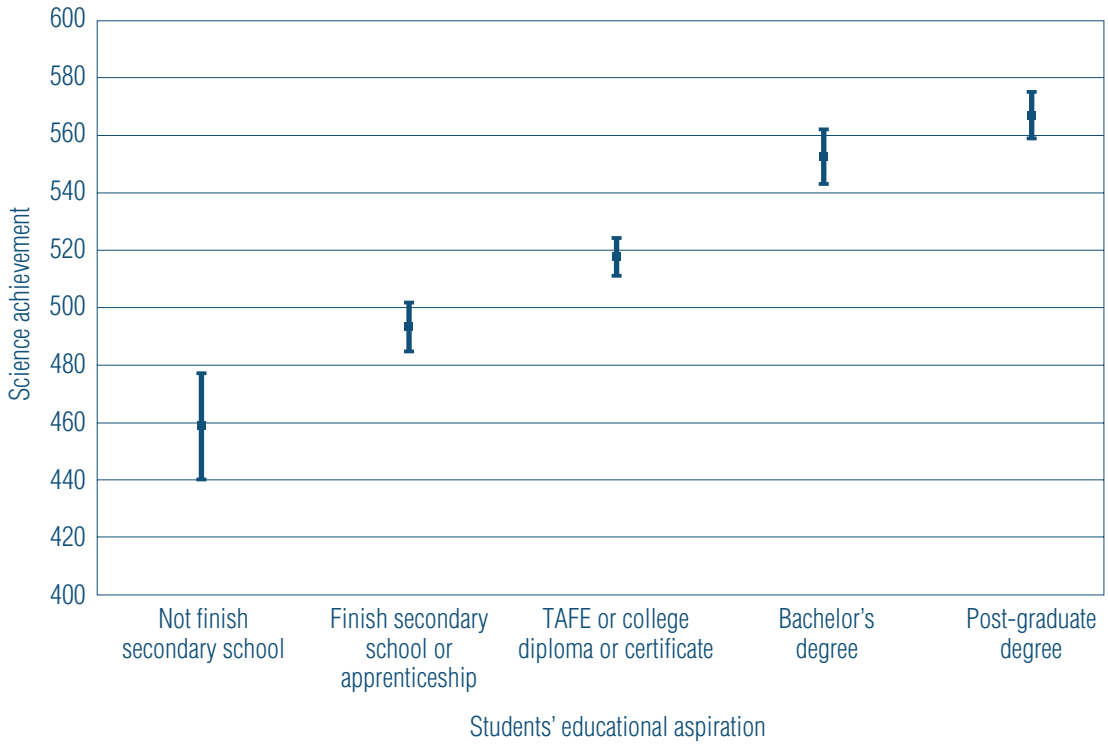


Figure 4.23 Year 8 science achievement by educational aspirations

Summary

This chapter has described the characteristics of the Australian Year 4 and Year 8 student populations, and has explored the relationships between these characteristics and achievement in science.

Year 8 students were asked the highest level of education reached by their mother and father. The highest of these was used as the parental education variable, and achievement in science was found to be higher for students whose parents had completed a university degree or higher. An index of home educational resources was also created, which combined parents' education, number of books in the home, and the presence of study aids (a desk, a dictionary and a computer), and three categories (high, medium and low) of students were defined. There was a clear relationship found between this index and achievement in science.

At Year 4, parents' educational level was not determined; however there was a clear and strong relationship between books in the home and achievement in science.

The scores of Indigenous students at both year levels was significantly lower than those of non-Indigenous students. For Year 4 students the difference between the scores of the two groups was slightly larger than in TIMSS 1994/95. However, at Year 8, the difference between the scores of the two groups was less than in TIMSS 1994/95. These differences will be explored in a follow-up report on Indigenous students.

The relationship between science achievement and language background was not clear. At Year 4 students who spoke English at home achieved at a significantly higher level than those who did not, while for Year 8, these differences were not apparent.

As well as student background characteristics, student attitudes towards learning science were examined. Australian students generally reported quite high levels of self-confidence in science, and while there was no gender difference at Year 4, self-confidence in science was higher for males than females at Year 8. There was a clear positive relationship between level of self-confidence and achievement in science.

Enjoyment of science is an important outcome in itself. Australia was one of a small number of countries that showed a significant increase at both year levels in the percentage of students who agreed 'a lot' that they enjoy learning science.

There were a wide range of student background factors, aspirations, out-of school activities and attitudes towards learning science that were investigated and reported in this chapter, along with their relationships with science achievement. The next chapter examines the contexts of their learning; the teachers who teach them and the schools in which they learn. Finally, a multilevel analysis is presented that draws together student, class and school factors that influence achievement in an 'other things equal' analysis.

Chapter 5
The contexts of learning science in Australia: TIMSS schools and teachers

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The contexts of learning science in Australia: TIMSS schools and teachers

This chapter examines the context for TIMSS students' learning – the schools that they attended and the teachers who were teaching them at the time of the testing. The aim of this examination is to describe those variables that are most likely to have an impact on or be associated in some way with achievement. Factors such as school environment, teachers' pedagogical practices and teacher preparation, among others, are variables that have been shown in TIMSS and other studies to be related to student achievement.

The chapter draws on data collected for TIMSS 2002/03 through questionnaires completed by teachers and principals. The unit for sampling of students within schools was their mathematics class, so that one mathematics teacher per school was asked to complete a questionnaire. However, in the case of Year 8 classes, not all students in a mathematics class also attended the same science class. In such cases, more than one science teacher per school was asked to complete a questionnaire. Year 4 classes, on the other hand, generally had the same teacher for mathematics and science so only one teacher questionnaire per class was completed. The science teachers' responses to the questionnaire were not necessarily representative of those of Australian science teachers, as these teachers were simply the teachers of a representative sample of students assessed as part of TIMSS 2002/03. The school questionnaires, however, should be representative of Australian schools as a whole because of the way the sampling was done. The information in this chapter should be thought of as indicative, and is provided for the purposes of setting achievement in context.

Just as the mathematics and science frameworks for TIMSS describe what should be assessed in those areas, the contextual framework identifies the major characteristics of the educational and social context that will be studied with a view to improving student learning. These major characteristics for the TIMSS 2002/03 study were:

Teachers and their preparation

- Academic Preparation and Certification
- Teacher Recruitment
- Teacher Assignment
- Teacher Induction
- Teacher Experience
- Teaching Styles
- Professional Development

Classroom activities and characteristics

- Curriculum Topics Taught
- Time
- Homework
- Assessment
- Classroom Climate
- Information Technology
- Computer Use
- Emphasis on Investigation
- Class Size

The schools

- School Organisation
- School Goals
- Roles of the School Principal
- Resources to Support Science and Science Learning
- Parental Involvement
- Disciplinary Environment of the School

This chapter provides a broad overview of each aspect of this framework. In Australia, responses were obtained from 91 per cent of the teachers and 98 per cent of the schools of the Year 4 students, and for 78 per cent of the teachers and 91 per cent of the schools of the Year 8 students.

Australian science teachers and their preparation for teaching

Age and gender

Nationally, three-quarters of Year 4 students were taught by females, and the majority were taught by teachers in the 40-49 year age group. This is around the same proportion as in TIMSS 1994/95, where 72 per cent of Year 4 teachers were women. Table 5.1 shows the gender distribution for Year 4 and Year 8 science teachers by state. Table 5.2 and Table 5.3 show the age distribution by state for Year 4 teachers and Year 8 teachers respectively.

Internationally most Year 4 students were taught by females. The international average is 79 per cent female teachers at Year 4. In Tunisia, however, most Year 4 students were taught by men (54%). In Morocco and Iran, a relatively high proportion (48% and 49% respectively) of Year 4 students had male teachers, while in Italy, Latvia, Lithuania, Moldova, the Russian Federation and Slovenia, more than 95 per cent of Year 4 students were taught by women.

In Australia, in all states other than South Australia (where 63 per cent of teachers were women) more than 70 per cent of Year 4 students were taught by women.

The picture for science teachers at Year 8 is somewhat different. In TIMSS 1994/95, 58 per cent of teachers were male and 42 per cent female; in TIMSS 2002/03 the national average was slightly less skewed – 46 per cent of students were taught by female teachers and 54 per cent by men. Internationally, however, Year 8 students are taught science more often by women than men. Students in the Australian Capital Territory are also taught by predominately female teachers (73%), while in New South Wales and Western Australia, the situation was reversed, with almost two-thirds of Year 8 students taught by male teachers.

On average, Australian Year 4 teachers had almost 17 years teaching experience, and Year 8 science teachers around 15 years experience. Both of these figures were very similar to the international average.

Given these years of experience, it follows that most students were taught science by teachers aged in their thirties and forties. This is certainly the case both in Australia and internationally, where around 60 per cent of both Year 4 and Year 8 students were taught by teachers aged between 30 and 49 years of age.

If there were a regular replenishment of trained teachers, one would expect that there would be approximately equivalent percentages of students taught by teachers in each age group. Very few countries, however, had a young teaching force. At Year 4 in Cyprus and Singapore, and at Year 8 in Botswana, Ghana, Lebanon and Saudi Arabia, more than four in ten teachers at Year 8 were under 30 years of age. One in five Australian Year 4 students, and a little less than one in four Year 8 students,

Table 5.1 Percentages of Year 4 and Year 8 science teachers by gender and state

State	Year 4			Year 8		
	N of teachers	% of students taught by a female teacher	% of students taught by a male teacher	*N* of teachers	% of students taught by a female teacher	% of students taught by a male teacher
NSW	55	81 (9.3)	19(9.3)	132	39 (6.9)	62 (6.9)
VIC	39	75 (7.0)	25 (7.0)	74	54 (8.2)	46 (8.2)
QLD	38	73 (8.2)	27 (8.2)	91	52 (8.1)	48 (8.1)
SA	41	63 (10.8)	37 (10.8)	52	41 (7.6)	59 (7.6)
WA	32	70 (8.8)	30 (8.8)	60	37 (10.4)	63 (10.4)
TAS	29	79 (9.5)	21 (9.5)	42	48 (11.2)	52 (11.2)
NT	22	81 (13.4)	19 (13.4)	31	58 (19.3)	43 (19.3)
ACT	16	73 (13.8)	27 (13.8)	54	73 (10.6)	27 (10.6)
Australia	272	75 (4.2)	25 (4.2)	536	46 (3.7)	54 (3.7)
International average		*79 (0.6)*	*21(0.6)*		*60 (0.5)*	*40 (0.5)*

Table 5.2 Percentages of Year 4 science teachers by age and state

State	Under 30	30–39	40–49	50 or older
NSW	21 (6.2)	9 (3.6)	65 (8.7)	5 (2.5)
VIC	26 (9.1)	10 (6.1)	34 (9.8)	29 (9.1)
QLD	17 (8.2)	29 (6.5)	29 (7.8)	26 (7.0)
SA	14 (6.3)	16 (8.1)	47 (7.8)	23 (8.1)
WA	22 (8.4)	13 (3.7)	36 (7.3)	28 (8.7)
TAS	29 (10.4)	0 (0)	29 (9.9)	32 (9.2)
NT	17 (10.2)	44 (14.7)	38 (14.3)	0 (0)
ACT	0 (0)	32 (9.5)	34 (12.7)	34 (11.6)
Australia	21 (3.5)	14 (2.4)	46 (4.4)	19 (3.0)
International average	*20 (0.7)*	*31 (0.8)*	*29 (0.8)*	*21 (0.7)*

had science teachers in their twenties. The proportion of students being taught by teachers who were less than 30 years of age has remained about the same since TIMSS 1994/95 for Year 4 students, whilst it is about four times that of TIMSS 1994/95 for Year 8 students.

At the other end of the age distribution, around one in five students internationally and in Australia, at both Year 4 and Year 8, were taught by teachers 50 or older. At Year 8 level more than half of the students in Italy and Macedonia had teachers at least 50 years of age.

In Australia, Year 4 students in Tasmania had the largest proportion of teachers under 30, although almost two-thirds were taught by teachers in their forties and fifties. Over 80 per cent of Year 8 students in the Northern Territory had science teachers in their twenties or thirties, whereas 75 per cent of students in the Australian Capital Territory had science teachers over 40 years of age.

Qualifications and training

Almost all (91% of Year 4 teachers and 90% of Year 8 teachers) Australian science teachers have full certification to teach, rather than provisional or emergency certification. This high level of certification of teachers was fairly common internationally, although in a large number of countries the level of full certification was higher than in Australia at both Year 4 level and Year 8 level. In Japan, for example, 99 per cent of Year 4, and 97 per cent of Year 8 teachers surveyed were fully certificated.

Table 5.4 presents the highest educational level attained by Australian Year 4 and Year 8 science teachers. Around one-quarter of Year 4 students in Australia were taught by teachers with some form of post-secondary education that was not university. For most of these teachers, this would be in the form of teachers' college training, and it is the older teachers who have this form of qualification. For the younger teachers, a university degree is the minimum qualification for being a teacher in Australia.

Table 5.3 Percentages of Year 8 science teachers by age and state

State	Under 30	30–39	40–49	50 or older
NSW	13 (5.2)	21 (4.2)	42 (7.8)	25 (6.6)
VIC	28 (8.3)	17 (4.7)	32 (7.5)	23 (6.6)
QLD	31 (7.9)	33 (5.9)	18 (6.4)	18 (7.3)
SA	31 (8.6)	18 (6.0)	29 (10.1)	23 (6.9)
WA	23 (6.6)	28 (11.2)	39 (11.2)	11 (5.8)
TAS	25 (9.4)	20 (3.7)	34 (8.5)	20 (10.0)
NT	23 (13.3)	60 (11.8)	1 (0.8)	16 (9.9)
ACT	7 (4.4)	19 (8.5)	43 (10.7)	32 (8.1)
Australia	23 (3.3)	23 (2.5)	33 (3.8)	21 (3.2)
International average	*20 (0.4)*	*30 (0.5)*	*28 (0.5)*	*22 (0.4)*

Table 5.4 Percentages of Year 4 and Year 8 science teachers by highest educational level

	Finished post-secondary education but not university	Finished university or equivalent	Beyond initial university degree
Year 4 teachers			
Females	24 (4.1)	52 (4.6)	23 (3.7)
Males	22 (7.4)	40 (8.9)	38 (10.3)
Australia	24 (3.4)	49 (4.4)	27 (4.1)
International average	*22 (0.5)*	*52 (0.7)*	*13 (0.5)*
Year 8 science teachers			
Females	6 (1.4)	38 (5.3)	56 (5.4)
Males	5 (2.5)	38 (5.0)	57 (4.8)
Australia	5 (1.5)	38 (3.7)	56 (3.5)
International average	*18 (0.3)*	*57 (0.4)*	*22 (0.4)*

Table 5.4 shows that the Australian teaching force is generally well educated. Internationally, 13 per cent of Year 4 teachers have postgraduate qualifications; for Australian teachers the average is more than twice this, at 27 per cent. For Year 8 science teachers, the international average is 22 per cent, and the Australian figure is two and a half times this, with over half of Australian science teachers having postgraduate qualifications: postgraduate diploma, honours, masters or doctorate. However, 40 per cent of these are postgraduate diplomas, which in many cases is the adjunct to an initial Bachelor's degree that is required to become a teacher. At Year 4 it was more commonly men who held the higher qualifications.

At Year 8 there was no difference between male and female teachers in the level of qualifications they held. An interesting note is that no Year 4 teachers and only eight per cent of Year 8 teachers in the highest scoring country, Singapore, held any form of postgraduate qualification. At Year 8, more than half of the students in Armenia, Australia, Bulgaria, Lithuania, New Zealand, the Russian Federation, Tunisia and the United States of America were taught by teachers having qualifications beyond their initial university degree, while in contrast, 44 per cent of students in Morocco were taught by teachers who had only completed secondary school.

Most teachers (72%) of Year 4 in Australia described the major area of study in their post-secondary education as primary education without a major specialisation in either science or science. This is true of many countries; similar proportions of generalist teachers teach Year 4 in most Western countries. In Iran, Latvia, Moldova, and the Russian Federation, around half of the students in Year 4 are taught by teachers with primary education training but with a major or specialisation in science, and in Armenia, 77 per cent of Year 4 students are taught by teachers with a science or science major but with no substantial primary teaching education.

Science teaching at Year 8 requires well-trained teachers with a sound knowledge of their subject matter as well as teaching skills. Bodies such as the Australian Association of Mathematics Teachers (AAMT) have warned of problems associated with increased use of teachers in mathematics and science who do not have adequate knowledge of the subject area (for example Thornton, 2002). However according to the responses from the Australian science teachers of the TIMSS students, 65 per cent had education-science as their major area of study, and 80 per cent had biology, physics, chemistry or earth science as their major area of study[1]. Only 10 per cent of science teachers at the Year 8 level did not have either science or education-science as their major area of study, and only 6 per cent had neither science nor mathematics as their major field of study.

[1] Teachers of Year 8 students answering the survey could indicate more than one area of specialisation, and so categories of education at this level are not mutually exclusive.

Readiness to teach

The TIMSS questionnaires asked teachers how ready they felt to teach the science topics in the TIMSS 2002/03 science framework. Year 4 teachers in Australia were most confident about their readiness to teach earth science, with over 90 per cent of teachers reporting that they felt ready to teach most of the topics in this content area (except for the topic of fossils of plants and animals, for which 82% reported readiness to teach). Australian Year 4 teachers were less confident about their readiness to teach topics in physical science (from 64% for forming and separating mixtures to 93% of teachers ready to teach common energy sources/forms and their practical uses) and life science (from 64 % for reproduction and development in plants and animals to 93% for changes in environments). For most of the framework areas, almost all Year 8 teachers in Australia reported that they were ready to teach the topic. The lowest agreement with this was 94 per cent for the area of trends in human population and its effects on the environment (environmental science).

Formal professional development

As well as having had opportunities to develop pedagogical expertise in their subject areas before they start to teach, it is important that teachers be provided with opportunities to continue to develop their expertise once they begin to teach. Teachers responding to the TIMSS surveys were asked to indicate the extent of opportunities for and participation in professional development activities. Of the Australian teachers surveyed, 85 per cent of Year 4 teachers and 93 per cent of Year 8 teachers had participated in professional development of some form during the previous two years. The area of professional development in which these teachers participated is summarised in Table 5.5. Of course teachers' participation in the particular areas of professional development is predicated on what is offered to them.

Professional development for Australian teachers of Year 4 students was mainly in the area of science content, science curriculum and improving critical thinking or problem solving skills. Professional development about science assessment was only undertaken by about one-fifth of Year 4 teachers. This was quite different to the pattern internationally, where there was quite a bit more emphasis on science assessment and a more even emphasis across all professional development areas.

As shown by the differences in the Australian and international averages, Australian Year 8 teachers participate in professional development to a greater extent than in many other TIMSS countries. At Year 8, professional development for Australian teachers is mainly in the areas of science content and curriculum. In the international data, the major areas of involvement in professional development were science content and pedagogy. Professional development in the area of improving students' critical thinking and problem solving skills had the lowest participation by Australian Year 8 teachers.

Principals were also asked about the opportunities for professional development for their staff. Their responses to these items are presented in Table 5.6. Internationally, at both Year levels, schools reported that their professional development programs emphasised improving content knowledge and teaching skills. In Australia, however, the three main areas for professional development for both Year levels were: designing and supporting the school's own improvement goals, improving teaching skills and integrating information and communication technology into education.

Table 5.5 Participation in areas of professional development for Year 4 and Year 8 science teachers, Australia and internationally

Area of professional development	Year 4 teachers (%)		Year 8 teachers (%)	
	Australia	International average	Australia	International average
Science content	38	37	69	58
Science pedagogy/instruction	27	37	57	56
Science curriculum	44	34	71	52
Integrating information technology into science	27	27	64	45
Improving students' critical thinking or problem solving skills	41	34	53	45
Science assessment	21	30	60	47

Table 5.6 Professional development opportunities for Year 4 and Year 8 science teachers

	Supporting the implementation of the state curriculum (%)	Designing or supporting the school's own improvement goals (%)	Improving content knowledge (%)	Improving teaching skills (%)	Using information and communication technology for educational purposes (%)
Year 4					
3 or more times a year	43	46	40	44	48
1–2 times a year	34	38	37	42	39
Never	23	16	23	14	13
Year 8					
3 or more times a year	48	60	40	50	46
1–2 times a year	38	35	48	47	50
Never	14	4	12	3	4

Informal professional development

As well as participating in formal professional development sessions, a great deal of informal professional development is conducted within a school – talking to other staff about teaching strategies, preparing instructional materials, and observing others teach. Teachers were asked how often they interacted with their colleagues in such a manner.

About 50 per cent of Australian teachers at both year levels interact with their colleagues on at least a weekly basis in order to discuss the teaching of a particular concept or topic. Only about ten per cent of teachers answered that they never or almost never spent time with their colleagues on such activities.

Again, a little more than half of both Year 4 and Year 8 teachers interacted with their colleagues on at least a weekly basis to prepare instructional materials for their students. A further 30 per cent of teachers at both levels spent some time (but not on a weekly basis) with their colleagues in such a manner.

Another important part of informal professional development is observation of other teachers, and having other teachers observe and critique your own classes. TIMSS teachers were asked about the frequency with which other teachers informally observed their teaching. Most Australian teachers said that this occurred on a very infrequent basis; however it was more common for this to occur amongst Year 4 than Year 8 teachers. Observations of another's classroom were also infrequent, with 81 per cent of Year 8 teachers and 68 per cent of Year 4 teachers saying that they rarely did this.

Classroom activities and characteristics

It is largely teachers and their practices that determine the implemented curriculum – the science that students are taught in their classrooms. The previous section of this chapter has examined the background of the science teachers in this study; this section examines classroom practices.

Factors limiting instruction in science

At Year 8 only, teachers were asked about the instructional impact of six characteristics of their students on a four-point scale – ranging from 'not at all' to 'a lot'. These six characteristics were:

- differing academic abilities,
- range in backgrounds,
- students with special needs,
- uninterested students,
- low morale, and
- disruptive students.

Teachers' responses were combined into an index called *Teaching science classes with few or no limitations on instruction due to student factors*, and is abbreviated SCFL. Students were placed into one of three categories based on the level of impact on their classrooms. Students were placed in the high category if, on average, their teachers reported 'not at all' or 'a little'; in the low category if on average their teachers reported 'some' or 'a lot'; and into an 'average' category in all other cases. That is, a high value on the SCFL index means that a classroom is relatively unaffected by these values and a low value indicates that these factors have a large impact on a classroom.

Table 5.7 Teachers' perceptions of factors limiting instruction in Year 8 science by state

State	High SCFL		Medium SCFL		Low SCFL	
	% of students	Average achievement	% of students	Average achievement	% of students	Average achievement
NSW	42 (7.8)	578 (11.5)	40 (6.1)	536 (14.9)	18 (4.5)	530 (12.3)
VIC	58 (7.2)	516 (7.2)	30 (6.3)	517 (8.4)	11 (5.1)	516 (19.9)
QLD	49 (8.0)	541 (6.6)	37 (8.8)	508 (9.4)	14 (5.6)	467 (10.1)
SA	36 (7.3)	549 (8.6)	38 (8.2)	524 (13.0)	26 (9.6)	477 (11.7)
WA	61 (9.4)	532 (9.0)	24 (6.1)	513 (14.3)	14 (7.7)	506 (27.5)
TAS	50 (11.4)	527 (11.5)	37 (9.0)	479 (14.9)	14 (4.9)	485 (45.3)
NT	24 (17.2)	509 (9.0)	48 (13.5)	495 (7.1)	28 (21.6)	425 (8.5)
ACT	51 (9.5)	551 (8.5)	33 (8.7)	521 (13.4)	16 (4.5)	538 (22.1)
Australia	49 (3.6)	541 (5.2)	36 (3.1)	522 (6.4)	16 (2.4)	504 (7.4)
International average	*38 (0.5)*	*486 (1.0)*	*40 (0.5)*	*469 (0.9)*	*21 (0.4)*	*457 (1.4)*

Internationally, it is clear that there is a relationship between these factors and achievement in science. Average science achievement is lower in classrooms with more instructionally challenging and diverse students. On average, internationally, one-fifth of students are in such classrooms, and this figure ranges from one per cent in Lithuania and Japan to 55 per cent in Iran. In Australia there are 16 per cent of classrooms in which instruction is hampered by factors such as these, compared to the United States of America in which there were 18 per cent, New Zealand with 20 per cent, Singapore with 23 per cent, and England with just nine per cent.

Within Australia there is slightly less variation than there is internationally. The index is shown for each state in Table 5.7, and shows the proportion of students in each of the three categories, and their average achievement score. Students in the Northern Territory and South Australia are affected the most by these issues, with 28 per cent and 26 per cent of students respectively attending classes seriously affected by such issues. In contrast, 61 per cent of students in Western Australia, and a half or more of the students in Victoria, Queensland, Tasmania and the Australian Capital Territory are in classrooms which are minimally impacted by such factors. The achievement scores of students in Victoria did not appear to vary, on average, with level of the index.

The responses of teachers in different states on the individual items of this index (shown in Table 5.8) are relevant for policy consideration in those states.

More than two thirds of teachers in the Northern Territory and one-half of the teachers in South Australia answered that their instruction was limited by students with differing academic abilities. Only one-third of teachers in Victoria, 38 per cent of those in New South Wales and 39 per cent of those in Western Australia answered in this way.

Around 40 per cent of teachers in the Northern Territory and South Australia also believed that their teaching was limited by the wide range of their students' backgrounds; which is about twice the proportion for any other state, and almost six times that of teachers in Victoria.

In comparison to the other items on this index, having children with special needs did not seem to be as much of a problem, perhaps because there is often extra assistance provided to support these students at school. New South Wales (29%) and Western Australia (25%) had the highest percentages of teachers reporting special needs as a limiting factor for science instruction.

The last three items on this scale deal with student motivation issues, and the effect these have on teachers' ability to deliver the curriculum. The first of these – uninterested students – is one of the major issues for teachers in most states, but most particularly in the Northern Territory, where 78 per cent of students are in classrooms where teachers feel their instruction is limited by this problem. Half or more of the teachers in New South Wales (51%), Victoria (53%), Tasmania (60%) and the Australian Capital Territory (49%) also felt that this was a major problem. While the proportions are still high, the states in which this is least a problem were Queensland (37%) and Western Australia (36%).

Low morale was less of a problem for teachers than uninterested students, but more than half of the Northern Territory teachers believed that it limited instruction. In Victoria and South Australia, 35 per cent of teachers, and in the Australian Capital Territory, 34 per cent of teachers, felt that low student morale impacted on their ability to teach science.

It is common in the classroom that uninterested students become disruptive students, and this indeed appears to be the case. Disruptive students are more of a problem in the Northern Territory, where 68 per cent of students are in classes in which their teacher has reported this as a factor limiting instruction in science. The only states in which the proportion of students in such classes is not close to or more than one-half, are Western Australia and Queensland, which have the lowest proportion of uninterested students.

Instructional time in science

On average, Australian Year 4 students spent about five per cent of their instructional time on learning science. Of this, about 40 per cent was spent on instruction in the area of *life science*, 30 per cent in the area of *earth science* and 20 per cent in *physical science*. The percentage of timetabled science class time is fourth lowest of the TIMSS Year 4 countries; however it is not very different from the international average of seven per cent. The Philippines had the highest percentage of timetabled science instruction at 15 per cent of total instructional time.

Students in Year 8 on average spent 13 per cent of their instructional time on learning science. This proportion was similar to the proportion of time spent on science instruction in countries such as New Zealand, the United States of America and Singapore. Of the timetabled science time, 26 per cent was spent in the area of *life science*, 23 percent in the area of *chemistry*, 21 per cent in the area of *physics*, 16 per cent in the area of *earth science*, and 11 per cent in the area of *environmental science*.

Scientific inquiry and investigations

Engaging students in scientific inquiry is an important part of the science curriculum in many countries. In order to investigate the emphasis placed on scientific investigations in the classroom, TIMSS asked Year 8 students and teachers how often students were asked to do the following:

- watch the teacher demonstrate an experiment or investigation,
- design or plan an experiment or investigation,
- conduct an experiment or investigation,
- work in a small group on an experiment or investigation
- write an explanation about what was observed and why it happened, and
- relate what was being learned in science to their daily lives.

Both students and teachers were asked to nominate whether every, or almost every, science lesson, about half the science lessons, or only some science lessons were spent on each of these activities.

Table 5.8 Teachers' perceptions of individual factors limiting Year 8 science instruction by state (% of teachers)*

	Different academic abilities		Range of backgrounds		Students with special needs		Uninterested students		Low morale amongst students		Disruptive students	
	None – a little	Some – a lot	None – a little	Some – a lot	None – a little	Some – a lot	None – a little	Some – a lot	None – a little	Some – a lot	None – a little	Some – a lot
NSW	59	38	62	22	56	29	47	51	67	29	48	50
VIC	63	33	82	7	71	10	44	53	60	35	34	62
QLD	57	44	77	22	67	22	58	37	74	21	57	43
SA	49	51	52	39	59	20	51	45	54	35	49	47
WA	60	39	68	21	52	25	53	36	65	17	55	39
TAS	52	49	61	17	61	20	40	60	79	20	42	58
NT	33	67	60	40	91	9	22	78	48	52	32	68
ACT	49	51	72	28	74	17	51	49	65	34	52	48

*Pairs of cells do not add to 100 as the response category 'Not applicable' is not reported in this table

In Australia, the most common activities (i.e. those in which students reported spending at least half of their class time) were:

- writing explanations about what was observed and why it happened (75% of students),
- working in small groups on an experiment (68% of students),
- conducting an experiment (60% of students),
- watching the teacher demonstrate an experiment (54%), and
- designing an experiment (49%).

The area of least attention was being asked to relate classroom science to their daily lives, in which 41 per cent of students reported spending at least half of their time in class.

According to their teachers, the most common responses were

- conducting experiments (73%),
- students working together in small groups on experiments (71%), and
- writing explanations about what was observed and why it happened (68%).

This was similar to the emphasis reported by students. However, students saw the classroom as more teacher dominated than teachers did – fewer teachers thought that most classes were spent with students watching them demonstrate an experiment (17%) or students designing experiments (19%). Almost two-thirds (63%) of teachers thought that over half their classes emphasised relating what was learnt to students' daily lives, and the slight dissonance between teacher and student responses suggests that this doesn't always connect with students as teachers may wish it to.

Internationally, teachers put more emphasis than Australian teachers on students watching them demonstrate an experiment (38%) and students designing experiments (31%) and slightly less emphasis than Australian teachers on conducting experiments (54%), working together in small groups on experiments (57%) and writing explanations about what was observed (61%).

The activity which received the most emphasis internationally was relating what was learnt to student' daily lives (76%). The whole international Year 8 student cohort was in agreement with their Australian counterparts, in that they felt that the greatest emphasis was on writing explanations (66% of students, internationally, reported that at least half their lessons involved this activity). However, more students internationally reported at least half their classes involving watching the teacher demonstrate an experiment (64%) and relating what they learnt to their daily lives (57%). Less students internationally than in Australia reported spending time in at least half their science classes working in small groups.

Teachers' beliefs about science and teaching science

Teachers' beliefs and understandings about science underpin the approach they take to teaching the subject. In TIMSS, Year 8 teachers were asked their level of agreement with nine statements about science. The results of this are presented in Figure 5.1.

The vast majority of Australian teachers agreed on five things, reflecting a constructivist way of teaching science – that solving science problems often involves hypothesizing, estimating, testing, and modifying findings, that more than one representation should be used in teaching a science topic, that there are many ways to conduct scientific investigations, that scientific theories are subject to change, and that modelling natural phenomena is essential to teaching science.

There is a lower level (66%) of agreement that science should be being taught primarily to give students the skills and knowledge to explain natural phenomena.

Of some concern is that almost one-fifth of the teachers surveyed agreed or strongly agreed with the statement that 'learning science mainly involves memorising', as memorising is a learning strategy that rarely leads to deep understanding. However, it is encouraging that science teachers see the value of what they are teaching, with less than five per cent of teachers agreeing with the statements that 'most scientific discoveries have no practical value' and 'getting the correct answer is the most important outcome of a student's scientific experiment'.

Instructional strategies

The science textbook is the foundation of science instruction in both Year 4 and Year 8 in most countries in the TIMSS study, although less so at Year 4. Australia and New Zealand stand out

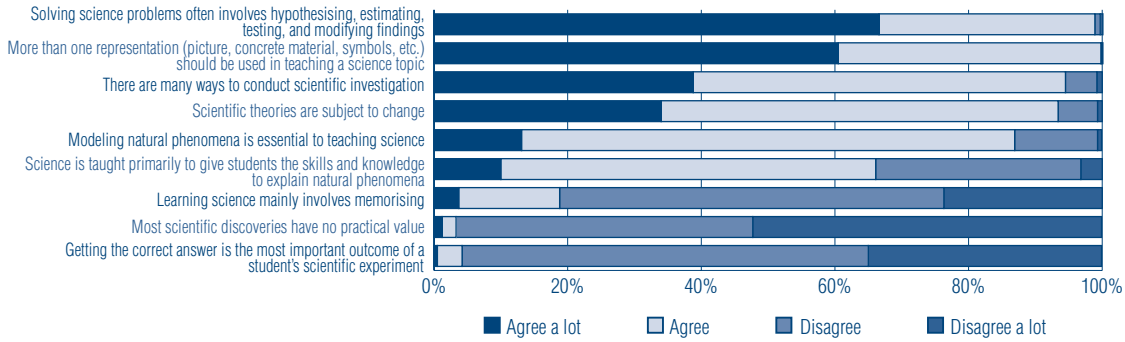

Figure 5.1 Australian Year 8 teachers' beliefs about science and teaching science

amongst the countries surveyed at Year 4 as having around 80 per cent of classes not using a textbook for science. In Belgium (Flemish), around half the science classes do not use a textbook. The proportion of classes not using a science textbook is about 40 per cent in England and Tunisia, around one quarter in Scotland and the United States of America, 18 per cent in Slovenia and 13 per cent in the Netherlands. In other countries, however, more than 90 per cent use a textbook, either as a primary basis for teaching or as a supplementary resource.

Of the 21 per cent of Australian Year 4 teachers who say they do use a textbook, only eight per cent use it as their primary resource. England and New Zealand are the only countries in which teachers use a textbook as a primary resource less than Australian Year 4 teachers.

At Year 8, Australia is one of only five countries where textbooks are not used in more than ten per cent of science classes. The other countries are Indonesia (54%), New Zealand (15%), Belgium (Flemish) at 14 per cent, and Malaysia (13%). In Australia, 19 per cent of teachers do not use a textbook at all, about one-third use it as their primary basis for lessons, and a half use it as a supplementary resource.

Activities in science classes

Year 8 students in Australia spend over a third (37%) of their class time working on problems with and without teacher guidance. This is about the same as the international average (33%), the United States of America (35%) and New Zealand (34%) but less than England (51 %) and more than Singapore (25%) and Chinese Taipei (15%). Another 29 per cent of class time was spent listening to teachers (both in lecture-style presentations and to re-teach and clarify procedures), and the remaining time reviewing homework (7%), taking tests (7%), participating in classroom management tasks unrelated to the lesson (8%) and other student activities (12%).

Computer use in science classes

Computer access is widespread in Australian schools. Eighty-four per cent of Year 4 students in Australia have access to a computer in their science classroom. While access is high, for science at this year level there is moderate usage with the primary use being to look up ideas and information, which occurs in about half of the lessons in about a quarter of Australian classrooms. However, the only country to have a higher proportion of teachers reporting using a computer within at least half their science classes was New Zealand (34%, for looking up ideas and information).

Seventy four per cent of Australian Year 8 science teachers have access to a computer in their classrooms. However, they are not utilised very much at all in science, with the most popular use being to look up ideas and information, which is reportedly done in at least half of lessons but in only six per cent of Australian classrooms. Most countries show similar levels of use of computers in science classrooms. Some exceptions are Korea, where 28 per cent of teachers use a computer frequently to study natural phenomena through simulations, and Chile, where 26 per cent of teachers use computers frequently to look up ideas and information.

Homework and assessment

The amount of time students spend on homework, and the types of homework that teachers set, are important considerations when examining opportunity to learn. TIMSS calculates a summary measure, an index of teacher's emphasis on science

homework (ESH). The teachers of students in the high category gave longer homework assignments on a relatively frequent basis (in half the lessons or more). Teachers of students in the low category gave short assignments (less than 30 minutes) relatively infrequently (in less than half the lessons). The medium level includes all other possible combinations.

Internationally, six per cent of Year 4 students were in the high category, a quarter had teachers that reported giving a medium amount of homework, and 69 per cent of students had teachers that reported having low emphasis on science homework. Across countries, not very many students had teachers in Year 4 that put a high emphasis on homework, the highest percentage being 27% in Moldova. Five countries had no teachers putting a high emphasis on science homework – the Netherlands, Japan, Cyprus, Scotland and Australia. In Australia, 95 per cent of Year 4 students had teachers that assigned little science homework infrequently.

At Year 8 level, there is often school policy involved in the setting of homework. The international average was 15 per cent for high emphasis on science homework, while about 40 per cent of the students were in the medium category. The range, however, was wide, from 44 per cent in the high category in Italy, through to one per cent in New Zealand and none in the Slovak Republic. More than three quarters of the students were in the low category in Serbia, Slovenia, Belgium (Flemish), Japan, Scotland and the Slovak Republic. In Australia, two per cent of Year 8 students had teachers with a high emphasis on science homework, 32 per cent in the average category, and 66 per cent in the low category.

Internationally, at both year levels, students of teachers reporting high levels of ESH had a lower average science achievement than students in the other two categories, suggesting that homework was often used for remedial purposes. There was no relationship between ESH and science achievement in Australia.

School contexts for science learning

There is a number of factors at the school level that influence the way that teachers are able to prepare and deliver the curriculum and the way in which students are able to learn what is taught. This section will describe the school-level contexts in which children learn science; internationally and within Australia.

School size and location

In Australia, the average school size for TIMSS Year 4 students was around 300 students, and for the Year 8 students it was around 630 students. The smallest school in the Year 4 assessment was 25 students, and the largest 1173 students, while for the Year 8 students the smallest school was 94 students and the largest 1970 students.

Figure 5.2 shows the location of schools in the TIMSS study. While the largest proportion of students are in urban regions of more than 500 000 people, there is a wide range, and almost the same proportion live in locations of between 3000 and 15 000 people. Around one in 10 Year 4 students and eight per cent of Year 8 students live in rural areas where the population is fewer than 1000 people.

Each school was located on the MCEETYA Schools Geographic Location Classification. Table 5.9 shows that just under two thirds of Australian

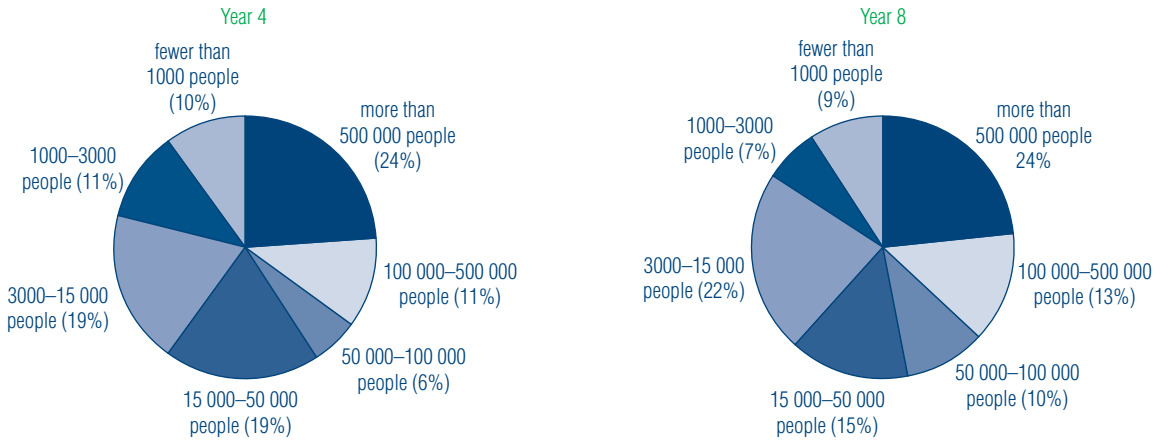

Figure 5.2 Location of schools for Year 4 and Year 8 students, in Australia

Table 5.9 Percentage of Australian students who attend schools in metropolitan, regional or remote areas and average science achievement

Location of school	Year 4		Year 8	
	% of Australian students	Average science score	% of Australian students	Average science score
Metropolitan	61	526 (4.4)	63	529 (5.5)
Regional	36	514 (9.3)	34	527 (6.5)
Remote	3	495 (12.7)	3	491 (13.9)

students attend schools in a metropolitan location, another third attend schools in regional areas and only 3 per cent attend schools in remote areas. At Year 4 there is no significant difference in average science score for students in each category. However, in Year 8, students in remote schools scored significantly lower than students in metropolitan schools.

School's socioeconomic composition

As well as examining student-level socio-educational background by asking students about their parents' educational level, TIMSS asked principals to report on the economic composition of their school, in particular by asking the approximate percentage of students in the school who come from economically disadvantaged homes. Principals were asked to assign a percentage from the following ranges: 0–10%, 11–25%, 26–50%, or more than 50%. A summary of the responses to this question for schools from both Australian populations is shown in Table 5.10. It would be assumed that schools with a low proportion of students from disadvantaged backgrounds will have greater resources and educational capital than schools with more than one-quarter of students from disadvantaged backgrounds.

About one-third of both Year 4 and Year 8 Australian students attend schools in which there are fewer than 10 per cent of the students who come from economically disadvantaged homes. This is the same as the international average for Year 4 students, but substantially greater than the international average for Year 8 students. At the other end of the scale, around 15 per cent of Year 4 students and fewer than one in ten Australian Year 8 students attend schools in which the principal reported that more than half of the students were from economically disadvantaged homes. At both year levels, but particularly at Year 8 level, these are much lower than the international averages.

This latter finding is to be expected given the much larger and more diverse range of countries that participated in TIMSS at Year 8. Indeed the range at Year 8 is very large. There was a number of countries where more than half of the students attended schools in which there were few disadvantaged students: Belgium (Flemish), Chinese Taipei, Japan, the Netherlands, and Singapore. There were also countries in which more than half of the students (50%–85%) attended schools in which more than half of the students were from

Table 5.10 Principal's reports on the percentages of students in their schools coming from economically disadvantaged backgrounds, Year 4 and Year 8, Australia and selected countries

	Schools with few (0–10%) economically disadvantaged students		Schools with between 11% and 25% economically disadvantaged students		Schools with between 26% and 50% economically disadvantaged students		Schools with more than 50% economically disadvantaged students	
	Year 4	Year 8	Year 4	Year 8	Year 4	Year 8	Year 4	Year 8
Australia	34 (4.4)	32 (4.6)	30 (4.0)	35 (4.2)	21 (3.6)	23 (3.3)	15 (4.0)	9 (2.3)
England	38 (4.4)	32 (5.3)	25 (4.5)	33 (6.0)	11 (3.0)	22 (6.2)	25 (4.2)	13 (4.2)
United States of America	19 (2.8)	28 (2.9)	23 (2.6)	23 (3.1)	20 (2.9)	25 (3.1)	38 (2.6)	24 (2.8)
New Zealand	44 (3.2)	36 (4.2)	22 (3.5)	30 (5.6)	12 (2.3)	16 (3.2)	22 (2.5)	18 (2.3)
Singapore	64 (3.7)	57 (0.0)	25 (3.2)	28 (0.0)	6 (1.7)	10 (0.0)	4 (1.6)	5 (0.0)
Hong Kong SAR	23 (4.4)	14 (3.5)	26 (3.5)	27 (4.0)	25 (4.9)	24 (3.9)	25 (4.4)	35 (4.6)
International average	*34 (0.7)*	*22 (0.5)*	*25 (0.8)*	*26 (0.5)*	*18 (0.7)*	*21 (0.5)*	*24 (0.7)*	*31 (0.5)*

economically disadvantaged homes: Chile, Ghana, Indonesia, Lebanon, Malaysia, Morocco, the Palestinian National Authority, the Philippines, Romania, South Africa and Tunisia.

In Figure 5.3 and Figure 5.4 the science achievement scores for Australia and the international average are plotted for each of the levels of reported economic disadvantage for Year 4 students and Year 8 students respectively. Figure 5.3 shows that for schools with large proportions of economically disadvantaged students, the Australian and international averages for Year 4 are similar, but the 'gap' between performance of Australian students and the international average increases for each level of economic disadvantage. In Figure 5.4 the Australian scores for Year 8 for each of the four categories of social disadvantage is shown, and for each of these categories, achievement of Australian Year 8 students is substantially higher than the international average. As well, the 'gap' between Australian Year 8 students' scores and those of the international average remains the same for all categories of disadvantage.

This 'gap' is larger for those schools with fewer disadvantaged students, suggesting that schools in Australia which have few disadvantaged students get an even bigger 'boost' in science scores than they do internationally. It could be hypothesised that schools with a lower level of disadvantaged students would also have a better level of access to resources in science, and so were able to teach the subject more thoroughly.

The difference in science achievement between the highest and lowest categories of economic disadvantage at Year 4 level is 69 score points; while for Year 8 students the difference is smaller, 47 score points. The international average differences were 44 points for Year 4 and 49 points for Year 8.

In some countries, there is less of a gap in the level of science achievement of those students in schools with a low proportion of disadvantaged

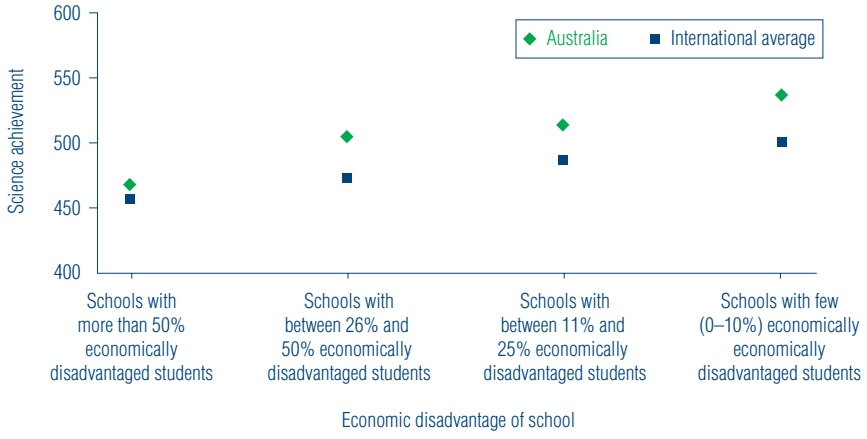

Figure 5.3 Relationship between economic disadvantage and science achievement for Year 4, Australia and the international average

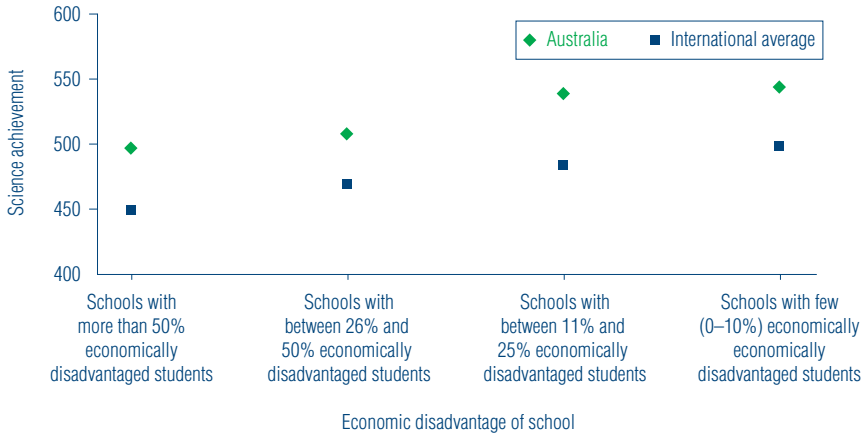

Figure 5.4 Relationship between economic disadvantage and science achievement for Year 8, Australia and the international average

students and those students in schools with a high proportion of disadvantaged students. In Hong Kong SAR, for example, the difference at Year 4 in the average science score for students in schools with few economically disadvantaged students and those in schools with more than 50 per cent economically disadvantaged students was half that of Australia: 32 score points. The ideal situation is that despite their social advantage or disadvantage, all students have the opportunity to succeed at school. While Figure 5.3 and Figure 5.4 provide some evidence that this is not the case in Australia, it is less marked than in countries such as Belgium (Flemish), for example, where the difference in average achievement for Year 8 students in science between these two categories of schools was 132 score points.

Perceptions of school climate

If we are trying to identify influences on student achievement, it is important to investigate the environment in which students learn. TIMSS 2002/03 created two new indices that indicate the extent to which schools offer a positive school climate, and this section relates these indices to student achievement. The indices were created from questions asked of both teachers and principals. Teachers and principals were asked to characterise, on a scale from very high to very low, each of the following within their school:

- teachers' job satisfaction,
- teachers' understanding of the schools' curricular goals,
- teachers' degree of success in implementing the schools' curriculum,
- teachers' expectations for students' achievement,
- parental support for students' achievement,
- parental involvement in schools' activities,
- students' regard for school property, and
- students' desire to do well in school.

A high rating on the principals' index (PPSC) indicated that principals averaged high or very high reports for each aspect of school climate. Students whose principals characterised school climate as medium were placed in the medium category and students whose principals characterised each aspect of the school climate as low or very low were placed in the low category. Similar categorisations were made for the teachers' responses to the items, forming the teachers' perception of school climate scale (TPSC). The averages on each of the indices, together with the international average, is shown in Table 5.11 for principals' perceptions and Table 5.12 for teachers' perceptions.

There is a clear relationship between principals' perceptions of school climate and science achievement at both year levels (a correlation of 0.21 at Year 4 and 0.18 at Year 8). On average, students in Australian schools that rated high on principal's perception of school climate scored about 70 score points higher than those students in the low PPSC category at Year 4, and about 65 score points higher at Year 8.

At Year 4, almost four in ten principals, and at Year 8 almost one-third of principals believed that their school had a very supportive and involved school climate, in which teachers were satisfied with their jobs, had a degree of success in implementing the curriculum, high parental support and involvement, and high levels of student engagement. This was a great deal higher than the international average for Year 4, and more than twice the international average for Year 8. In contrast, fewer than one in

Table 5.11 Index of principals' perception of school climate (PPSC) at Year 4 and Year 8, Australia and the international average

	High PPSC		Medium PPSC		Low PPSC	
	% of students	Average achievement	% of students	Average achievement	% of students	Average achievement
Year 4						
Australia	38 (4.6)	538 (4.5)	55 (5.1)	514 (4.4)	7 (3.6)	468 (36.6)
International average	*23 (0.7)*	*510 (2.0)*	*66 (0.8)*	*486 (1.1)*	*11 (0.5)*	*457 (3.8)*
Year 8						
Australia	31 (4.3)	541 (7.0)	61 (4.8)	529 (5.3)	8 (2.7)	476 (19.9)
International average	*15 (0.4)*	*499 (2.2)*	*67 (0.6)*	*473 (0.8)*	*18 (0.4)*	*455 (1.9)*

Table 5.12 Index of teachers' perception of school climate (TPSC) at Year 4 and Year 8, Australia and the international average

	High TPSC		Medium TPSC		Low TPSC	
	% of students	Average achievement	% of students	Average achievement	% of students	Average achievement
Year 4						
Australia	31 (3.6)	532 (7.3)	59 (3.7)	526 (3.3)	11 (2.5)	466 (25.7)
International average	*20 (0.6)*	*508 (2.5)*	*67 (0.8)*	*488 (1.2)*	*13 (0.5)*	*467 (2.5)*
Year 8						
Australia	13 (2.1)	559 (7.2)	57 (3.5)	534 (5.5)	30 (3.9)	499 (6.6)
International average	*10 (0.3)*	*496 (2.4)*	*60 (0.5)*	*477 (0.8)*	*30 (0.5)*	*460 (1.1)*

ten Australian principals rated their school as low on this index.

At Year 4 there was strong agreement between principals and teachers, with a little less than one-third of teachers rating their schools as having a good school climate and only one in ten rating it as low. Year 8 principals were, however, far more optimistic about their school climate than the teachers in their schools. At Year 8, fewer than one in six teachers rated their schools as high on the school climate scale, whilst more than one in four rated it as low. Australian Year 4 teachers, in general, more positive than that of the international average but there was not much difference between Australian Year 8 teachers' perceptions of school climate and the international average.

There was a similar relationship between teachers' perceptions of school climate (TPSC) and achievement as between achievement and principals' reports of school climate (a correlation of 0.17 at year 4 and 0.26 at Year 8). On average, those students whose teachers rated their schools as high achieved 66 scale score points higher than those in low TPSC schools at Year 4, and 60 scale score points higher at Year 8.

Absenteeism and other school discipline problems

In some countries, student absenteeism is a serious problem. Schools that deal with high levels of absenteeism also confront problems of instructional continuity and reduced time for learning. To examine this issue, TIMSS developed an index of good school and class attendance that is based on schools' responses to three items about the seriousness of student absenteeism, arriving late at school, and skipping class. Research has suggested that higher levels of truancy are related to less serious attitudes to school and lower academic achievement. High scores on this index indicate that none of these behaviours are a problem, while low scores on the index indicate that either two or more behaviours are a serious problem, or two a minor and the third a serious problem. The medium category includes all other possible combinations of responses.

Table 5.13 shows the proportions of Year 4 and Year 8 students in Australia attending schools reported by their principals to be in each category, and also the average achievement score for each category. At Year 4, internationally 47 per cent of principals rated their schools as having few if any attendance problems, compared to 41 per cent of Australian principals. Only five per cent of principals internationally compared with four per cent of Australian principals believed that problems with school and class attendance was a serious problem. However this ranged a great deal. More than three-quarters of the principals in Slovenia and Chinese Taipei judged their schools as having few problems with attendance, while one fifth of those in Morocco and Moldova, almost one in seven of those in the Philippines and one in ten of those in Armenia thought that attendance was a serious problem.

At Year 8, as would be expected because as students get older discipline problems often get worse, the picture was not as good. Internationally, less than one-quarter of principals rated their school as having little or no problems with school or class attendance rates, whereas almost one in five admitted to this being a serious problem. The Australian proportions were similar to this, as can be seen in Table 5.13, with the main difference being fewer students in the 'low' category. The range internationally was not quite as large as with the Year 4 students. In Lebanon,

Table 5.13 Index of principals' perception of good school and class attendance (GSCA), at Year 4 and Year 8, in Australia

	Australia	
GSCA	% of students	Science achievement
Year 4		
High	41	532
Medium	55	513
Low	4	480
Year 8		
High	26	548
Medium	61	528
Low	13	500

Italy, Republic of Korea and Chinese Taipei, more than half of the students were in schools categorised as having no serious problems with issues around absenteeism. In contrast, around four in ten of the students in Japan, Estonia, South Africa, Lithuania, Latvia and Bulgaria, attended schools where the principal believed that attendance was a serious issue for their school. As would be expected, achievement levels are higher in those schools with high levels of good school and class attendance, and lower in those schools with low levels of school and class attendance (a correlation, in Australia, of 0.15 at Year 4 and 0.2 at Year 8).

Organisation of science instruction

There are many ways in which science instruction in a school can be organised, and the way in which it is organised may have repercussions for the students at the school. Principals were asked how their school organises science instruction for Year 8 students with different levels of ability. In 45 per cent of Australian schools, principals said that all students study the same curriculum, regardless of ability, and a further 44 per cent of principals said that students studied the same science curriculum, but at different levels of difficulty. In only a very few schools (11%), principals said that students study different science curricula according to their ability. Principals were asked explicitly whether Year 8 students were grouped by ability for science, and 19 per cent answered yes. In 40 per cent of these schools, as seen in Figure 5.5[2], all students are streamed or grouped according to ability. Schools were then equally divided in their manner of dealing with students of varying abilities with 30 per cent teaching the highest ability and lowest ability students separately and 30 per cent separating out the highest ability students only.

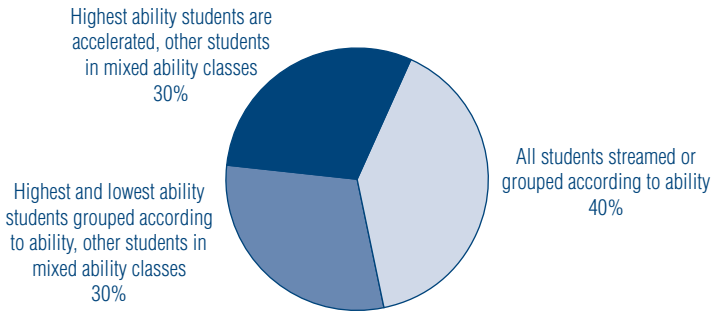

Figure 5.5 Manner of grouping students if the school streams for science at Year 8, in Australia

[2] Comparative international data were not available for this item

Availability of school resources for science instruction

While there are some resources in a school specific to science, many are general resources that improve learning across the curriculum. TIMSS has in previous studies calculated an index of the availability of school resources for science instruction (ASRSI) in each of the participating countries[3]. In TIMSS 1994/95 and TIMSS 1998/99 it was found that schools that were generally well resourced had higher average science achievement than those in which shortages in resources affected instruction capacity in some manner. The index is based on principals' average response to five questions about shortages that affect the school's general capacity to provide instruction, and five questions that target the provision of instruction in science specifically. Students were placed in a high category if principals reported that shortages had little or no effect on science instruction, the medium level if one shortage affects instruction to some extent, and low if both shortages affect instruction some or a lot. The proportion of students in each of the groups both for TIMSS 1994/95 and for the current study, are shown in Table 5.14.

At Year 4, there has been a significant increase between 1994/95 and 2002/03 in the proportion of students in schools with few shortages that affect instruction. This is similar to the trend internationally, where the proportion of students in schools with few shortages has increased from just over 22 per cent to 28 per cent. In Australian primary schools, this proportional increase has reflected a decline in the proportion of schools with medium ASRSI – those with shortages in one area or another. The same decline can be seen internationally. However of some concern is the increased proportion of students in schools with shortages in both areas. This is not a real concern in Australia, with very few schools teaching Year 4 students reporting such levels of shortages.

While the proportion of Australian students in the High ASRSI group is substantially above the international average, it is a great deal lower than for countries such as Singapore (85%), Scotland (51%), Slovenia (49%) and Japan (48%).

More than half of the Year 8 students in Australia are in schools with high ASRSI, and this has significantly increased since TIMSS 1994/95. The proportion of students in both medium and low ASRSI has declined since TIMSS 1994/95, but not significantly. The highest achieving country, Singapore had 92 per cent in the highest category. The Australian proportion of students in this category was equivalent to that of Hong Kong SAR, Belgium (Flemish), New Zealand, the United States of America and a number of other countries.

Table 5.14 Trends in the index of availability of school resources for science instruction (ASRSI), Australia and the international average

	High ASRSI		Medium ASRSI		Low ASRSI	
	1994/95	2002/03	1994/95	2002/03	1994/95	2002/03
	% of students	% of students	% of students	% of students	% of students	% of students
Year 4						
Australia	24 (4.6)	**38 (3.9)**	**74 (4.5)**	59 (4.0)	5 (2.0)	3 (0.8)
International average	*22 (1.0)*	***28 (0.7)***	***72 (1.1)***	*62 (0.9)*	*7 (0.6)*	***11 (0.6)***
Year 8						
Australia	42 (5.2)	**55 (3.8)**	52 (5.4)	43 (3.8)	6 (2.3)	2 (1.3)
International average	*22 (0.9)*	***26 (0.5)***	***66 (1.0)***	*63 (0.6)*	*12 (0.6)*	*12 (0.4)*

Figures in bold indicate that the proportion is significantly higher than the proportion for the other group of students

[3] The index is based on principals' average response to items about shortages affecting general capacity to provide instruction (such as instructional materials, budget for supplies, school buildings and grounds, heating, cooling and lighting, and instructional space) and shortages affecting science instruction (such as laboratory equipment and materials, computers and computer software, calculators, library resources and audio-visual resources).

Student perceptions of school safety

TIMSS asked students five questions that examined their perceptions of how safe they were in their school. These questions tapped into students' perceptions of whether they were subjected to a level of bullying in their schools. Students were asked to answer 'yes' or 'no' to whether each of the following things had happened in the last month:

- Something of mine was stolen
- I was hit or hurt by other students
- I was made to do things that I didn't want to do by other students
- I was made fun of or called names
- I was left out of activities by other students.

The responses to these items were used to create the index of students' perception of being safe in school. Students who reported being in a safe environment (i.e. those who felt a low level of bullying), answering 'no' to all five statements, were placed into the high category on this index. Students who reported being in a less safe environment (those who were bullied on a regular basis) by answering 'yes' to all of these statements were placed in the low category. All other response patterns were included in the medium category. Table 5.15 provides the percentage of students in Australia and the international average for each of the categories.

The percentage of Australian students in the high category, that is those students who answered 'no' to all of the items listed, was lower than the international average, while the percentage of students in the 'low' category was higher than the international average, particularly at Year 4. For Year 4 there was a direct positive relationship between students' reporting being in safer schools and higher science achievement, however there appears to be no relationship at Year 8.

The country with the lowest proportion of students who feel bullied at school in Year 4 were Armenia (5%), Norway (13%) and Lithuania (13%), and in Year 8 were Sweden (3%), Serbia, the Netherlands and Belgium (5%). The countries with high proportions of students who feel as though they are bullied at school in Year 4 were the Philippines (50%) and Chinese Taipei (35%). The next highest proportions were for New Zealand and Australia, both with 32 per cent of students who feel they are bullied on a regular basis. In Year 8, the countries with the highest proportion of students in the 'low' perception of safety category were Jordan (61%), South Africa (40%) and the Philippines and Ghana (38%).

Table 5.15 Index of students' perceptions of being safe at school, at Year 4 and Year 8, Australia and the international average

	Students' perception of school safety					
	High		Medium		Low	
	% of students	Average score	% of students	Average score	% of students	Average score
Year 4						
Australia	29 (1.0)	535 (3.9)	39 (1.0)	525 (4.9)	32 (1.4)	508 (4.8)
International average	*35 (0.3)*	*502 (1.7)*	*42 (0.2)*	*488 (1.0)*	*23 (0.2)*	*471 (1.3)*
Year 8						
Australia	43 (1.2)	530 (4.2)	40 (1.0)	529 (4.1)	18 (0.9)	524 (4.3)
International average	*48 (0.2)*	*484 (0.8)*	*37 (0.1)*	*474 (0.7)*	*15 (0.1)*	*458 (1.0)*

Multilevel analyses

Over the past two chapters we have looked at the student, teacher and school level factors that have an influence on science learning and achievement for Australian students. Some of these factors may have a direct influence on achievement; others may have influences that are mediated through other variables. This section examines the effect of these factors, taking into account the concomitant influences of other related factors and the multilevel structure of the data – that is, students grouped or 'nested' within classes.

Hierarchical linear modeling was used to examine the net effects of factors at the student and class levels. This procedure provides an indication of the influence of one factor under the condition that the influence of the other factors was equal. It also allows modeling of outcomes at two levels (e.g. student level, classroom level), partitioning separately the variance and effects at each level while controlling for the variance across levels. In this sense it allows for the fact that students within a classroom will be more similar to each other than to students in other classes or schools.

The analyses were conducted separately for Year 4 and Year 8. Because only one class per school was sampled in Australia, a two-level analysis (classroom and student) was conducted. All independent variables were normalised to a mean of zero and a standard deviation of one.

Variables included in the analyses

Table 5.16 provides details of the variables that were used in the analyses. In the table, variables are organised in groups as student-level and classroom-level variables.

Table 5.16 Student and class variables used for multilevel science analyses

Student-level	
Student background variables	
Sex	Student's gender
Possessions	Number of possessions relating to family wealth
Books	Number of books in the home
Age	Student's age
Indigenous	Indigenous status
Language background	Whether the student speaks English at home or not
Parents' education	Highest of parents' educational level
Aspirations	Student's aspirations to higher education
Student mediating variables	
Science homework	Amount of science homework the student does regularly
Computer usage	Breadth of use of computers
Self-confidence in science	Student's level of confidence in science
Perceptions of safety	Student's perceptions of their level of safety in the school
Self-confidence	Student's self-confidence in science
Classroom-level variables	
Years taught	Number of years teacher has been teaching
Education	Level of education of teacher
Training	Level of teacher training of teacher
Informal PD	Level of informal professional development of teacher
Formal PD	Level of formal professional development of teacher
TPSC	Teacher's perception of school climate
ESH	Teacher's emphasis on science homework
Science time	Amount of time allocated to science
Stream	Whether school streams in science
PPSC	Principal's perception of school climate
GSCA	Principal's perception of good school and class attendance
Disadvantage	Proportion of students from disadvantaged backgrounds
ASRSI	Availability of school resources for science instruction
Location	Area in which school is located, based on MCEETYA index

Influences on science achievement – Year 4

A two-step analysis was conducted (using MlWiN) to investigate which factors were significant influences on science achievement at Year 4 in Australia. The initial model (null model) was used to estimate the amount of between-class and within-class variance. This indicated that 20 per cent of the variance in students' science achievement was attributable to differences between classrooms (between-class) and 80 per cent of the variance in science achievement was attributable to differences between individuals (within-class). It should be noted that because TIMSS 2002/03 only sampled one class per school, the variance at the second level of the multilevel analysis combines what would normally be school-level and class-level variance. In other words, because we only have one classroom per school, we are unable to determine how much of the variance that we are describing at the second level of the model is variance that occurs between classes in the school, or variance that occurs between schools.

In the second step of the analysis a range of classroom and student level variables, as shown in Table 5.16, were included in the analysis. The model was then tested iteratively. At each iteration any variables that were not statistically significant were removed until the model only contained variables with a significant influence. Results are presented in Table 5.17.

The final model of influences on Year 4 students' science achievement includes 11 factors – nine at the student level and two at the school/classroom level. Together, these nine factors explain 27 per cent of the variance in science achievement scores. Of the remaining unexplained variance, seven per cent is the result of differences between schools/classrooms and 66 per cent is attributable to differences between students.

Students' ethnic and language background have a strong effect on science achievement, other things equal. The strongest influence on Year 4 science achievement was whether the student speaks English at home most of the time. Predominantly English-speaking students achieved, on average, 23 score points higher than those students who did not speak English at home on a frequent basis. Most of the science questions involve an amount of reading, and so it is possible that this explains this relationship; however further investigation is needed. Indigenous status is the next strongest influence, but in a negative direction. Indigenous students achieved, on average, 20 points below their non-Indigenous counterparts.

The role of self-confidence is important, as it is one of the variables in the analysis that is amenable to change. Self-confidence in learning science has one of the strongest relationships with science achievement, other things equal. Students who fall into the medium category of the self-confidence in learning science index achieve, on average,

Table 5.17 Estimates of influences on science achievement in schools, Year 4

	Coefficient (standard error)
Intercept	**508.2 (7.6)**
Student level variables	
Language background	22.9(4.4)
Self-confidence	19.8 (1.7)
Indigenous	–18.9 (4.9)
Books	13.4 (1.5)
Science homework	–8.3 (1.9)
Computer usage	7.8 (1.5)
Gender	–7.4 (2.4)
Perception of safety	7.1 (1.5)
Possessions	5.5 (1.5)
School and classroom level variables	
GSCA	12.9 (3.0)
Disadvantage	–11.9 (2.6)
Variance	
Explained by the model	27%
Unexplained school level (between-schools)	7%
Unexplained student level (within-schools)	66%

20 points higher than students in the low category. Students in the high category achieve another 20 points (on average) on top of that. However, as we have not been able to control for either prior science achievement or earlier self-confidence in learning science, it is not possible to determine whether it is the self-confidence in learning science that influences science achievement or vice versa, or indeed if it is a reciprocal relationship.

Socio-educational influences also had a positive effect on science achievement. A moderately strong influence on science achievement at Year 4 was the number of books in the home – a positive influence with students gaining 13 points per step of the index. Also a positive influence was the availability of computers, with students who had access to computers at both home and school achieving about 8 points higher than students who did not have access to a computer in one or both of these locations.

Receiving more homework (that is being in either the medium or high categories of the homework index) was negatively associated with science achievement. Students who received medium amounts of science homework scored about 8 points below those receiving low amounts and those in the high category were a further 8 score points lower again. It is likely that this reflects the usual assignment of homework to weaker students, that weaker students spend more time on homework than higher achieving students or that weaker students take longer to do the same amount of homework.

Students' perception of safety at school also had an impact on science achievement – the safer a child felt (or the less they feel bullied), the higher their level of science achievement (about 7 points for each step on the scale). Number of possessions in the home was also positively related to science achievement, with each extra possession associated with about five extra points on the achievement scale. Gender was negatively associated with science achievement; at Year 4, being female and holding other things equal, meant a score of about 7 points lower than being male.

Two of the school and classroom level variables were found to have significant effects on achievement in science at Year 4: the index of good school and class attendance, and the proportion of economically disadvantaged students in the school. Students attending schools that scored higher on the index of good school and class attendance had higher achievement (13 points per category on the index) than those students whose principal reported problems in the area of school and class attendance. Students' scores would be expected to be about 12 points lower for each level on the economic disadvantage scale, so those students in a school with more than 50 per cent of economically disadvantaged students would score, on average, 36 points less, all other things equal, than a school with less than 10 per cent economically disadvantaged students.

This analysis provides some valuable information for schools and policy makers. A number of the factors that have a significant effect on student achievement in science at Year 4 reflect socioeconomic background, language background or Indigenous status, and while none of these can be altered, provision can be made to support learning for each of these groups. However there are other factors that are amenable to change – student self-confidence, perceptions of safety, and good school and class attendance. These last two in particular suggest particular strategies that primary schools can use to improve learning in science – they need to provide an environment in which children feel safe, and they need to deal with problems of absenteeism to ensure instructional continuity and to provide ample time for learning to occur.

Influences on science achievement – Year 8

As at Year 4, a two-step analysis was conducted to investigate which factors were significant influences on science achievement at Year 8. The initial model (null model) was used to estimate the amount of between-class and within-class variance. This indicated that 37 per cent was attributable to differences between schools/classrooms (between-class) and 53 per cent of the variance in science achievement was attributable to differences between individuals (within-class).

In the subsequent analysis the school/classroom and student level variables were included. The model was then tested iteratively. Again, at each iteration any variables that were not statistically significant were removed until the model only contained variables with a significant influence. Results are presented in Table 5.18.

The final model of influences on Year 8 students' science achievement includes 11 factors – ten at the student level and one at the school/classroom level. Together, these 11 factors explain 37 per cent

of the variance in science achievement scores. Of the remaining variance, 16 per cent is the result of differences between classes and 47 per cent is attributable to differences between students.

At Year 8, the ethnic and language background of the student is very influential on science achievement. The effect on achievement of Indigenous status is even greater at Year 8 than at Year 4, and the strongest influence on science achievement at Year 8. Indigenous students at Year 8 achieved, on average, 34 points below their non-Indigenous counterparts. The next strongest influence is that of speaking English at home. Predominantly English speaking students achieved, on average, 18 points higher than those students who did not speak English at home often. Again, this warrants closer examination.

Educational aspirations were the next largest influence on Year 8 science achievement, with each step of the aspirations index adding an extra 14 points to a student's science achievement score. Gender differences were also apparent; other things equal, females on average scored 13 points less than males in science at Year 8. Books in the home had a similar sized effect, with an extra 13 points per step on the scale.

The effect of self-confidence in learning science is not as strong for Year 8 students as for Year 4 students; however other things equal, it is still a moderately strong influence. Students who fall into the medium category of the self-confidence in learning science index achieve, on average, 12 points higher than students in the low category. Students in the high category achieve another 12 points (on average) on top of that.

The next factors, parent's education, the availability of computers, valuing of science and age, all have a weak but significant effect on student achievement. Computer usage adds about 7 points for each extra place in which the student accesses computers. Parents' educational level adds about six points to the science achievement score for each step of the scale. The degree to which students value science has a positive influence that adds about five points to the scores of students who place a medium value on science (as compared to students who place a low value on science) and another five points for students who place a high value on science.

The final influence on Year 8 science achievement is age. Age has a very minor negative influence on science achievement, which means that older students are not achieving as well as younger students, all other things being equal. There are two possible reasons for this – younger students in the sample are likely to be those who have been promoted out of their age group because they have a high level of ability or who began school early, while older students in the sample may have been retained in grade at some stage because of poorer performance. The fact that age only has an effect on students in Year 8 supports this hypothesis; at Year 4, students have generally not had enough time at school to have been either promoted or retained in grade.

Table 5.18 Estimates of influences on science achievement in schools, Year 8

	Coefficient (standard error)
Intercept	**557.2 (6.4)**
Student level variables	
Indigenous	–33.9 (5.7)
Language background	18.5 (4.7)
Aspirations	14.1 (1.4)
Books	13.2 (1.3)
Gender	–13.0 (2.3)
Self-confidence in science	11.8 (1.5)
Computer usage	6.6 (1.7)
Parents' education	5.4 (1.4)
Valuing science	4.3 (1.5)
Age	–3.1 (1.4)
Classroom level variables	
Disadvantage	–12.2 (3.0)
Variance	
Explained by the model	37%
Unexplained school level (between-schools)	16%
Unexplained student level (within-schools)	47%

Summary

This chapter has examined a wide range of the contextual factors that may have an impact, either directly or indirectly, on the science learning of the TIMSS students. This information was primarily obtained from the teacher and school questionnaires; however an item from the student questionnaire is also reported in this section as it pertains directly to the classroom or school environment.

The chapter profiled the science teachers of the TIMSS students: their age, qualifications, training and experience, readiness to teach, and use of professional development. The surveys showed that most Year 4 students and almost half Year 8 students were taught science by women, and that most teachers were in the 30–49 years age group. Most teachers felt prepared to teach most subjects, and participated in some form of professional development throughout the year.

The chapter also reviewed teachers' and principals' views about classroom characteristics that were hypothesised to impact on learning. These included factors limiting instruction in science (students with differing abilities, students with special needs, uninterested students, low morale and disruptive students), time on instruction, use of scientific inquiry, teachers' beliefs about science and teaching science, instructional strategies, computer use, and homework and assessment usage.

In some states, there appear to be factors limiting instruction that are not apparent in other states. In the Northern Territory and South Australia in particular, there appeared to be problems with the wide range of students' abilities, the wide range of student backgrounds, and in the Northern Territory, with uninterested students, low levels of student morale and disruptive students. The majority of teachers surveyed agreed with statements reflecting a constructivist way of teaching science, although around one-fifth supported the use of learning strategies such as memorisation.

The use of textbooks in science is lower in Australia than in most other countries in TIMSS. Most teachers of Year 4, and 20 per cent of science teachers in Year 8, do not use a textbook as their primary resource in science lessons. Computer use was low in most schools despite high availability, and at both year levels, teachers did not assign their classes a great deal of homework.

An examination was conducted of the influence of various aspects of school contexts on science learning. This examination included factors such as school size and geographic location, school socioeconomic composition, perceptions of school climate, absenteeism and other school discipline problems, availability of resources for instruction, and students' perceptions of school safety.

Geographic location did not have an effect on science achievement, other than Year 8 students in remote schools scoring at a significantly lower level than students in metropolitan schools. Socioeconomic composition did have an effect on science achievement, with achievement levels higher in schools with low proportions of students from disadvantaged economic backgrounds. Not surprisingly perhaps, student achievement was also higher in schools in which principals reported high levels of teacher satisfaction and cohesion, where teachers had high expectations of their students, parents were supportive and involved, and students were engaged and had high expectations of themselves. Again, and not surprisingly, achievement was lower in schools where absenteeism, truancy and late arrivals were a problem.

Finally, this chapter examined a range of variables at student, class and school level in a two-level multilevel model. All factors were included and then removed in an iterative process that left only the significant net effects on science achievement.

At Year 4, two of the largest influences on achievement, other things equal, were the ethnic and language background of the student. Those students who did not speak English at home and those students with an Indigenous background did not do as well as other Australian students. This suggests that a higher level of support for these students needs to be provided and maintained.

Two variables that can be influenced by schools were self-confidence and good school and class attendance. Students' self-confidence is a significant factor in achievement and can be encouraged not only by the classroom teacher but also by the school climate, as can regular and timely attendance at school.

At Year 8 the largest influences were ethnic and language background, in a similar manner to that for Year 4 students. Also significant, however, were students' aspirations to tertiary study, gender

(males achieving higher than females), books in the home and self-confidence in learning science.

In summary, this chapter has identified some of the factors at the class and school level that are related to student learning in science. However some of these factors have stronger influences than others. Indigenous students, students whose language background is other than English, and students in schools with high levels of economically disadvantaged students, may need to have greater support with their learning in science than other groups. Students with high levels of self-confidence tend to achieve well in science, and this can be nurtured within the classroom. Lastly, a school climate which is supportive, and which encourages attendance and high aspirations, will almost certainly lead to higher science achievement.

The final chapter of this report provides a summary of the findings from the TIMSS Science study, and suggests some policy matters that result from these findings.

Chapter 6
Summary and policy considerations

Chapter 6 Summary and policy considerations

This report describes the achievements in science of Australian students in the Trends in International Mathematics and Science Study (TIMSS) conducted in Australia and other southern hemisphere countries in 2002 and in northern hemisphere countries in 2003. Just over 10,000 Australian students participated in TIMSS, along with students in 45 other countries, from both developed and developing parts of the world. A parallel report focussing on achievement in mathematics is published concurrently to this report (Thomson & Fleming, 2004).

TIMSS 2002/03 is the latest in a series of international tests in mathematics and science, going back to the mid 1960s. It is the third combined mathematics and science study in which Australia has participated; others being the Third International Mathematics and Science Study (TIMSS 1994/95), and the partial repeat of TIMSS at Year 8 level only (TIMSS 1998/99). Australia's participation in TIMSS provides an opportunity to continue to build a comprehensive picture of trends in achievement in mathematics and science for students in Year 4 and Year 8. Although Australia participated in TIMSS 1998/99, the results from this study are not used as a comparison in the current reports, due to changes in the definition of populations. These trends will be examined in a later report. The current report uses Population 1 (Year 4) and Population 2 (Year 8) data from TIMSS 1994/95 for comparison with TIMSS 2002/03 data, and can thus look at changes in science achievement over an eight year span.

This report details the achievement in science of Australian students in Year 4 and Year 8 both in an international context and for the six Australian states and two territories. The samples of schools and students in TIMSS were large and representative, and smaller states were oversampled so that accurate estimates can be made. Response rates were generally high, and quality control methods strictly applied. Australia reached the required participation rates for the Year 8 sample, and for the Year 4 sample with replacement schools.

To complement the achievement data, TIMSS also collected contextual information from a range of sources, including school systems, and the principals, teachers and students in the schools selected for participation in TIMSS. This allows analysis of achievement results in relation to many of the contextual variables that are suggested by other research to improve performance.

Achievement in science in an international context

Australian students acquitted themselves well in science at both Year 4 and Year 8. However Australia's achievement in science has remained statistically the same since TIMSS 1994/95 for Year 4 students, while the performance of a number of other countries significantly improved over this period, raising their position relative to that of Australia. Australian Year 4 students were outperformed by two countries only in TIMSS 1994/95, but by seven countries in TIMSS 2002/03.

The achievement scores for Year 8 students significantly increased over the period from TIMSS 1994/95 to TIMSS 2002/03. Other countries' scores also increased, however, and some by large amounts, so that in TIMSS 2002/03, three more countries joined the three who, in TIMSS 1994/95, had significantly higher scores than Australia.

In TIMSS 1994/95 there were significant gender differences in many of the TIMSS countries at both year levels, and in all of these males outperformed females. In Australia, males performed significantly better than females at Year 4, but there were no gender differences at Year 8. In TIMSS 2002/03 gender differences were not all in favour of males, however this was more apparent at Year 4 than at Year 8. At Year 4, almost half of the significant gender differences and the larger differences found were in favour of females.

International benchmarks were developed by the International Study Centre to describe performance at four levels. These were the *advanced*, *high*, *intermediate* and *low* international benchmarks.

Nine per cent of Year 4 students and nine per cent of Year 8 students in Australia achieved the advanced international benchmark. For both year levels this was higher than the international average of seven per cent for Year 4 students and six per cent for Year 8 students. At Year 4, 92 per cent of Australian students reached at least the low international benchmark, and this was substantially higher than the international average of 82 per cent. The proportion of Year 8 students achieving at least the low international benchmark was 95 per cent, which compared extremely well to the international average of 78 per cent. The proportion of Australian Year 4 students at the advanced benchmarks has declined since TIMSS 1994/95, while the proportion of Australian Year 8 students has remained the same.

In Australia at Year 4, there were no gender differences in achievement of the benchmarks, however in Year 8, a larger proportion of males than females achieved the advanced benchmark and fewer males than females failed to achieve the low benchmark.

The highest achieving country at Year 4, Singapore, achieved 25 per cent of students at the advanced international benchmark, and 95 per cent at the lowest benchmark. Twelve other countries at Year 4 achieved a higher proportion than Australia of students achieving the low international benchmark.

Singapore was also the highest scoring country at Year 8, and 33 per cent of their students achieved the advanced benchmark and 95 per cent the lowest international benchmark. Ten other countries at Year 8 level achieved a higher proportion of students achieving the low international benchmark than Australia.

Achievement was also examined in the separate science content areas. Year 4 students scored significantly higher than the international average in each of the three content areas (*earth science*, *life science* and *physical science*). Year 8 students also scored significantly higher than the international average in the five content areas defined for this year level; however their strongest area was *environmental science* and their weakest area *chemistry*.

In Year 4, females outperformed males in *life science*, however there were no gender differences for the other two content areas. In Year 8, however, males substantially and significantly outperformed females in all content areas other than *life science*.

Comparisons can also be made across the states of Australia, although there are some structural differences in school starting ages that make comparisons more difficult. Students start school at various ages throughout the states, and some students start directly into Year 1 while others complete a preparatory year before Year 1, meaning that students in two states (Queensland and Western Australia) may be younger than their counterparts in other states and have up to a year less formal schooling.

The only significant difference in Year 4 science in TIMSS 2002/03 was for Western Australia, which scored significantly lower than the Australian Capital Territory. This is quite a different picture than that for Year 4 science in TIMSS 1994/95, when Western Australia significantly outperformed all states other than South Australia. For Year 4 students in TIMSS 2002/03, the Australian Capital Territory was the highest scoring state, with an average score around the same as that of the two highest scoring countries.

In Year 8 science in TIMSS 2002/03, there were again few differences. New South Wales achieved at the highest level, scoring internationally at about the same level as Chinese Taipei, the second highest scoring country, and almost as high as Singapore. This represents an increase in achievement for New South Wales students, who were outscored by students in Western Australia, the Australian Capital Territory and South Australia in TIMSS 1994/95. Students in all states other than the Northern Territory achieved an average score that was higher than the international average. The Northern Territory's score was at the international average level. In TIMSS 1994/95, the scores of four states: New South Wales, the Northern Territory, Tasmania and Victoria were similar to the international average in science.

States also varied in the achievement of the international benchmarks in science. At Year 4, the Australian Capital Territory had the greatest proportion of its students reaching the highest and lowest international benchmark, while the Northern Territory had the lowest proportion reaching either the advanced or low benchmarks.

At Year 8, New South Wales had the highest proportion reaching the advanced international benchmark, and the Australian Capital Territory had the highest proportion reaching the low international benchmark. The Northern Territory again had the lowest proportion reaching either the advanced or low international benchmarks.

Achievement in science by Indigenous students continues to be a matter for concern. Overall, Indigenous students scored well below the Australian average and therefore well below the international average at both year levels; however there did seem to be a small decrease in the gap between the scores of Indigenous students and all Australian students between TIMSS 1994/95 and TIMSS 2002/03 at Year 8. Further analysis will be done with the Indigenous sample obtained from TIMSS 2002/03.

Gender differences were apparent in a number of attitudinal areas. Males at both Year 4 and Year 8 were found to be more self-confident in learning science; and they profess to enjoy science to a greater degree than females do.

A large number of student, class and school variables were examined individually in relation to achievement, and then many were used in multilevel models that attempted to explain the variance in science achievement at both year levels, holding other things equal. The findings from these models were that most significant factors for Year 4 science were language background, Indigenous status and self-confidence. For Year 8 science the most significant factors were Indigenous status, language background, and to a much lesser extent, students' intentions to pursue further education.

Policy issues arising from TIMSS

Science is regarded as one of the foundation areas of learning in the compulsory years of schooling. Studies in other curriculum areas, and many occupations in modern society, require a broad base of scientific literacy. A recent national review of teaching and teacher education in science, technology and mathematics argued that changing social and economic conditions provided an imperative to strengthen and broaden the base of knowledge and skills in mathematics and science developed through Australia's school systems (Committee for the review of teaching and teacher education, 2003).

The results from TIMSS 2002/03 indicate that achievement in science at Year 4 in Australia has remained virtually the same since TIMSS 1994/95, while the achievement levels of a number of other countries, including neighbours, trading partners and countries with which we have traditional ties, have improved. Achievement scores in science at Year 8 have increased significantly, but, as with Year 4, so have those of other countries. The results obtainable from large, comparative international studies such as TIMSS demonstrate that over a relatively short period of time, large improvements can be made in science achievement. This report provides a broad overview of student achievement and the factors that are related to it; however there are many ways in which this rich database can be used to gain further insight as to why there has been little change in Australia's performance in science relative to other countries in eight years.

The gender difference in Year 8 science is an issue that is of some concern and needs further investigation. Males outscored females in all aspects of science at this year level; they were over-represented at the advanced benchmark and females were more likely to not achieve the low benchmark; males were also more self-confident and enjoyed science more than females did.

The achievement levels of Indigenous students in core learning areas such as science are another concern. There is some indication that levels of achievement in science are improving for Indigenous Australians, and this will be investigated in depth in a further report arising from these data.

From other studies there are indications of areas that might provide a focus for improvement. The review of teaching and teacher education pointed to the uncertainties regarding how best to teach science and mathematics in primary schools, a need to strengthen the development of content and pedagogical knowledge in mathematics and science during initial education and continuing professional development, and a need to attract to, and retain in, the teaching profession graduates with strong backgrounds in science (Committee for the review of teaching and teacher education, 2003). Perspectives from other studies are neither comprehensive nor definitive but they are consistent with the findings of TIMSS 2002/03. The results from TIMSS 2002/03 suggest that further investigation and thoughtful responses in policy and practice will be important to sustain and enhance science learning in Australian schools.

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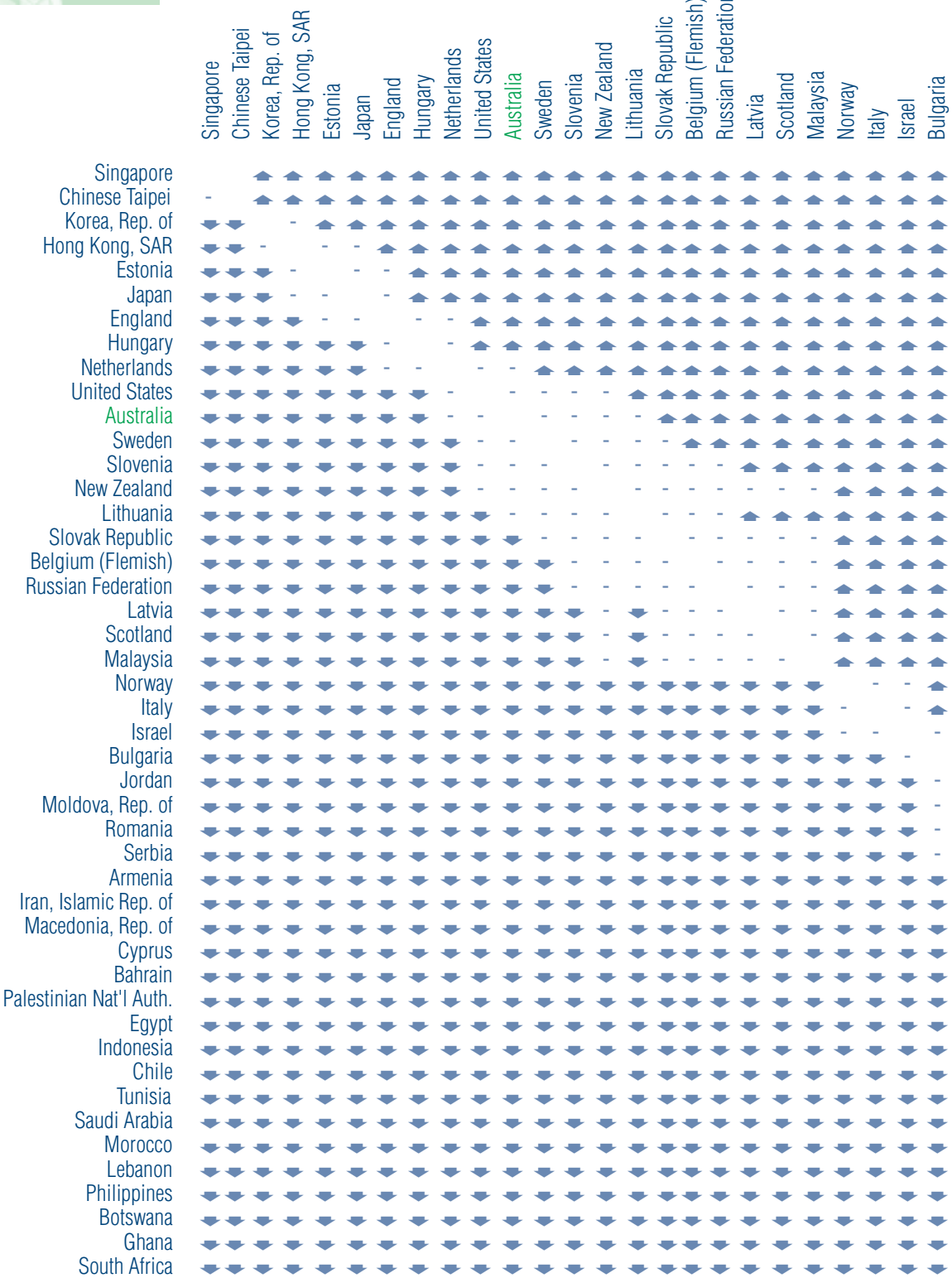
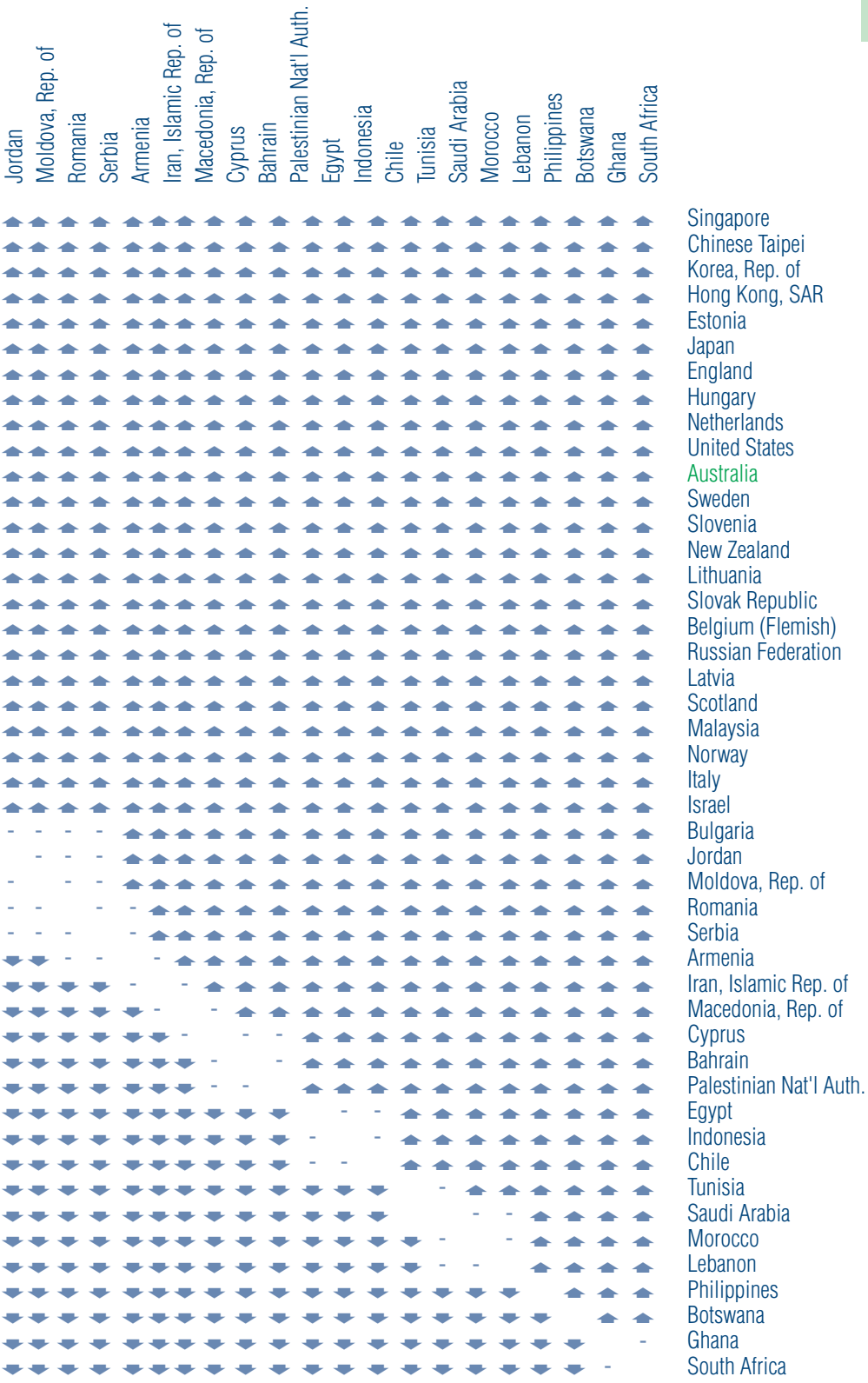
Appendix 1
Multiple comparisons of average science achievement for all countries

Year 8



▲ Average achievement significantly higher than comparison country
▼ Average achievement significantly lower than comparison country

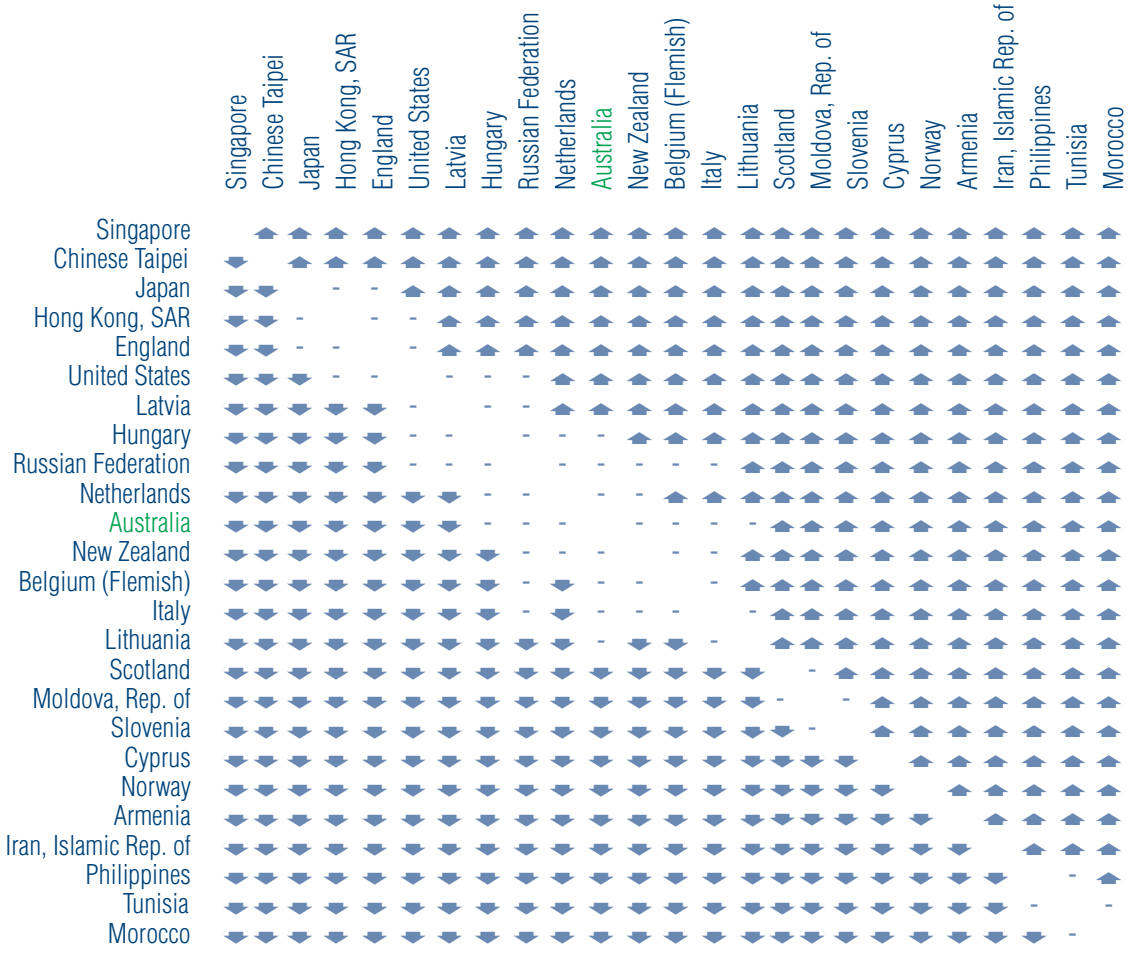
Instructions: Read across the row for a country to compare performance with the countries listed along the top of the chart. The symbols indicate whether the average achievement of the country in the row is significantly lower than that of the comparison country, significantly higher than that of the comparison country, or if there is no statistically significant difference between the average achievement of the two countries.



Note: 5% of these comparisons would be statistically significant by chance alone.
SOURCE: IEA Trends in International Mathematics and Science Study (TIMSS) 2003

Year 4

Instructions: Read across the row for a country to compare performance with the countries listed along the top of the chart. The symbols indicate whether the average achievement of the country in the row is significantly lower than that of the comparison country, significantly higher than that of the comparison country, or if there is no statistically significant difference between the average achievement of the two countries.



▲ Average achievement significantly higher than comparison country
▼ Average achievement significantly lower than comparison country

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