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Australian Students Achievement in the TIMSS 2002 Mathematics Cognitive Domains

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Contents

Tables

Figures

Executive Summary

The TIMSS assessment materials are organised on the basis of two domains: a content domain and a cognitive domain. The content domain describes the content that is intended to be assessed; while the cognitive domain describes the cognitive abilities students use to answer the items. The content domains are fairly consistently and readily found in the curricula of the participating countries, and are the subject of the major international and national reports for TIMSS. Developing reliable and valid achievement scales for the cognitive domains is not as straightforward, and differences among students across and within countries in their mathematical knowledge and problem solving skills make it difficult to know which cognitive abilities students are using to solve a particular mathematical or scientific problem. This report examines findings about the TIMSS cognitive domains from an Australian perspective.

The content domains defined in the *TIMSS 2003 Assessment Frameworks and Specifications* (Mullis, Martin, Smith, Garden, Gregory, Gonzalez, Chrostowski & O'Connor, 2003) were number, algebra (or patterns and relationships at year 4), measurement, geometry and data. Four cognitive domains were also described in the Frameworks – knowing facts and procedures, using concepts, solving routine problems and reasoning.

The domains defined for the TIMSS mathematics cognitive scales were: *knowing facts, procedures and concepts*; *applying knowledge and understanding*; and *reasoning*. The first domain, *knowing facts, procedures and concepts*, covers what the student needs to know, while the second, *applying knowledge and conceptual understanding*, focuses on the ability of the student to apply what he or she knows to solve routine problems or answer questions. The third domain, *reasoning,* goes beyond the solution of routine problems and simple recall of facts to encompass unfamiliar situations, complex contexts, and multi-step problems.

At Year 4 level, Australian students scored at a level not significantly different from the international average in *knowing* and *applying*, but significantly higher than the international average in *reasoning*. Within Australia, the Australian Capital Territory was the highest scoring state in each of the cognitive domains.

At this year level, some states achieved a score higher than the international average in some domains, but none in all three. Students in the Australian Capital Territory scored higher than the international average in the *knowing* cognitive domain; the ACT, New South Wales and Victoria scored higher than the international average in the *reasoning* cognitive domain. No state scored at a higher level than the international average in the *applying* cognitive domain.

Year 4 students' relative strengths were in the content domains of *measurement*, *geometry* and *data* and their relative weakness was in the content domain of *number*. In the cognitive domains, students' relative strength was in the *reasoning* cognitive domain and they were relatively weak in the *applying* cognitive domain.

At Year 8 level, Australian students performed above the international average in all three cognitive domains. Students in Singapore achieved the highest average scores in the *applying* and *reasoning* cognitive domains. Within Australia, New South Wales was the highest scoring state in all three cognitive domains. Students in New South Wales, Victoria, Queensland, South Australia and the Australian Capital Territory performed above the international averages in all three cognitive domains. Western Australia achieved above the international averages in *applying* and *reasoning* and students in Tasmania achieved above the international average in *reasoning*.

Australian Year 8 students' relative strength was in the *data* content domain, and their relative weakness was in the *geometry* content domain. In the cognitive domains, Year 8 students' relative strength was in *reasoning* and their relative weakness was in the area of *knowing.*

Australian Students' Achievement in the TIMSS 2002 Mathematics Cognitive Domains

1. Defining the TIMSS Cognitive Domains

Overview of TIMSS

Conducted first in 1994/95, and again in 1998/99 and 2002/03, the regular four-year cycle of the Trends in International Mathematics and Science Study (TIMSS) provides countries with an opportunity to obtain comparative information about their students' achievement in mathematics and science. Towards the end of 2002, just over 10,000 Australian students in Year 4 and Year 8 participated in the third cycle of TIMSS, along with students in the same year levels in 48 other countries[1]. TIMSS tests students' achievement in mathematics and science, and collects a rich array of information about the school and home contexts for learning mathematics and science. Full details about the design and implementation of TIMSS 2002 in Australia are presented in the national reports: *Summing it up: Mathematics achievement in Australian schools in TIMSS 2002* (Thomson & Fleming, 2004a) and *Examining the evidence: Science achievement in Australian schools in TIMSS 2002* (Thomson & Fleming, 2004b).

The TIMSS content and cognitive domains

The assessment material in TIMSS is organised on the basis of two domains: a content domain and a cognitive domain. The content domain describes the content intended to be assessed, while the cognitive domain describes the cognitive abilities students use to answer the items. The TIMSS content domains are fairly consistently and readily found in the curricula of the participating countries. However, developing reliable and valid achievement scales for the cognitive domains is not as straightforward. Differences among students across and within countries in their mathematical knowledge and problem solving skills make it difficult to know which cognitive abilities students are using to solve a particular mathematical or scientific problem. In previous TIMSS cycles, only achievement in the TIMSS content domains was reported.

Despite these difficulties, however, many countries had expressed an interest in having comparative information about students' performance in the cognitive domains as well as information about performance in the content domains. To this end, a developmental project was carried out by the TIMSS International Study Center to map the TIMSS 2002 items onto the cognitive domains and then develop and report cognitive scales in mathematics. The mathematics expert group which met to consider the mapping found there was some overlap between the domains, and so they used the existing framework to develop three mutually exclusive domains for reporting the TIMSS 2002 cognitive results. In classifying items, the expert group followed the guidelines of classifying items according to the cognitive process they thought most students would use. Further work is being carried out to develop cognitive scales in the TIMSS science assessment. The full report on the international findings on the TIMSS cognitive domains has been published (Mullis, Martin & Foy, 2005). This report examines the findings in more detail from an Australian perspective.

To respond correctly to the TIMSS mathematics test items in the 2002 assessment, students needed to be familiar with the mathematics content of the items, and just as importantly, items were also designed to elicit the use of particular cognitive skills. In previous cycles of TIMSS, items were not written for the explicit purpose of reporting on the cognitive domains, only for reporting on the content domains. The content domains defined in the *TIMSS 2003 Assessment Frameworks and Specifications* (Mullis, Martin, Smith, Garden, Gregory, Gonzalez, Chrostowski & O'Connor, 2003) were number, algebra (or patterns and relationships at year 4), measurement, geometry and data. Four cognitive domains were also described in the Frameworks – knowing facts and procedures, using concepts, solving routine problems and reasoning.

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1 As testing is carried out towards the end of the school year, most southern hemisphere countries tested at the end of 2002 while northern hemisphere countries tested during the first half of 2003.

Development of the cognitive scales

These domains defined for the TIMSS mathematics cognitive scales were:

- Knowing facts, procedures and concepts;
- Applying knowledge and understanding; and
- Reasoning.

The first domain, *knowing facts, procedures and concepts*, covers what the student needs to know, while the second, *applying knowledge and conceptual understanding*, focuses on the ability of the student to apply what he or she knows to solve routine problems or answer questions. The third domain, *reasoning,* goes beyond the solution of routine problems and simple recall of facts to encompass unfamiliar situations, complex contexts, and multi-step problems. Whilst there is not a definitive hierarchy, it is fairly clear that one builds on the other.

The distribution of items within the three cognitive domains, the five content domains, and by item difficulty and item type was also examined, to ensure adequate coverage of all cognitive domains. Table 1.1 and Table 1.2 show for Year 4 and Year 8 respectively, the percentage of score points by content and cognitive domain.

Table 1.1 Percentage of score points in TIMSS Year 4 mathematics by content and cognitive domain

Content domain	Cognitive domain			Total score points
	Knowing	Applying	Reasoning	
Number	37%	29%	34%	68
Patterns and relationships	8%	54%	38%	24
Measurement	31%	56%	13%	32
Geometry	72%	24%	4%	25
Data	24%	41%	35%	17
Total	**36%**	**39%**	**26%**	**166**
Number of Items	**58**	**63**	**38**	**159**

Table 1.2 Percentage of score points in TIMSS Year 8 mathematics by content and cognitive domain

Content domain	Cognitive domain			Total score points
	Knowing	Applying	Reasoning	
Number	35%	55%	10%	60
Algebra	43%	23%	34%	53
Measurement	21%	73%	6%	33
Geometry	30%	36%	33%	33
Data	15%	53%	32%	34
Total	**31%**	**46%**	**23%**	**213**
Number of Items	**65**	**93**	**36**	**194**

There was a substantial number of items in each cognitive domain, and within each domain there was found to be a good spread of item difficulty. Recognising that there is some unevenness in some areas, this study has informed the development of the TIMSS 2007 assessment in which an effort has been made to redress issues of imbalance. Some examples of TIMSS test items for each of the cognitive domains follow.

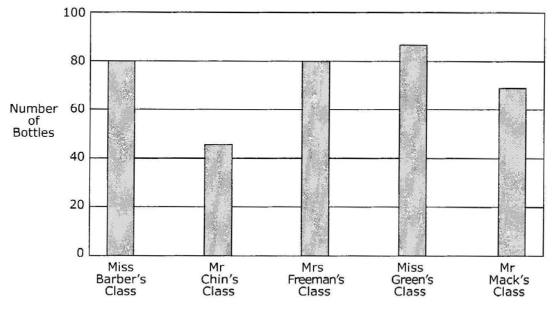
Knowing facts, procedures and concepts

Facility in using mathematics, or reasoning about mathematical situations, depends to a large extent on the student's mathematical knowledge and familiarity with mathematical concepts. The greater the student's automatic recall of facts, procedures and concepts, the greater the ability to make extensions beyond their existing knowledge and to apply their skills to more complex problems.

Facts encompass the factual knowledge that provides the basic language of mathematics, and the essential mathematical facts and properties that form the foundation for mathematical thought. *Procedures* provides a bridge between basic factual knowledge and the use of mathematics for solving routine problems, particularly those encountered in people's daily lives. Knowledge of *concepts* allows students to make connections between pieces of knowledge that would otherwise be retained as isolated facts. Such knowledge allows students to make extensions beyond their existing knowledge, judge the validity of mathematical statements and create mathematical representations.

The first two examples illustrate items that should be straightforward to students at the appropriate year levels. The first example, shown in Figure 1.1, is a straightforward multiple-choice item for Year 4 in which students are expected to be able to read a graph and respond appropriately. Figure 1.2 requires Year 8 students to recognise that 4/5 of 10 squares is 8 squares, and that they would need to shade in a further 5 squares to answer correctly.

Centretown School had a bottle collection. Children in each class brought empty bottles to school. The principal made a graph of the number of bottles from five classes.



Which class collected 45 bottles?

- Ⓐ Miss Barber's class
- ● Mr Chin's class
- Ⓒ Mrs Freeman's class
- Ⓓ Mr Mack's class

Figure 1.1 Example of Year 4 item for *Knowing* cognitive domain, *Data* content domain

In the figure, how many MORE small squares need to be shaded so that $\frac{4}{5}$ of the small squares are shaded?

- ● 5
- Ⓑ 4
- Ⓒ 3
- Ⓓ 2
- Ⓔ 1

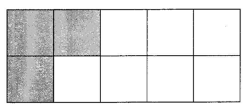


Figure 1.2 Example of a Year 8 item for *Knowing* cognitive domain, *Measurement* content domain

Applying knowledge and understanding

Problem solving is often a central aim of school mathematics teaching, and therefore problem solving and its supporting skills (e.g. select, represent, model) are prominent features of this cognitive domain. To demonstrate skills in this domain, students need to apply mathematical knowledge of facts, skills and procedures or understanding of mathematical concepts to create representations and solve problems. The problem settings are more routine than those associated with the *reasoning* domain, and the problems are expected to be sufficiently familiar to students so that they will essentially involve selecting and applying learned procedures.

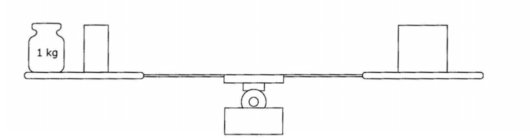
Two examples of items that tap into this cognitive domain follow. In Figure 1.3, Year 4 students are required to apply their knowledge of volume to a word problem, and in Figure 1.4, Year 8 students are required to apply basic algebraic skills to solve a word problem.

Kim made a stack of cubes of the same size. The stack had 5 layers and each layer had 10 cubes. What is the volume of the stack?

Ⓐ 5 cubes
Ⓑ 15 cubes
Ⓒ 30 cubes
● 50 cubes

Figure 1.3 Example of Year 4 item for *Applying* cognitive domain, *Measurement* content domain

The objects on the scale make it balance exactly. On the left pan there is a 1 kg weight (mass) and half a brick. On the right pan there is one brick.



What is the weight (mass) of one brick?

Ⓐ 0.5 kg
Ⓑ 1 kg
● 2 kg
Ⓓ 3 kg

Figure 1.4 Example of Year 8 item for *Applying* cognitive domain, *Algebra* content domain

Reasoning

Reasoning mathematically involves the capacity for logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems. Non-routine problems are problems that are likely to be unfamiliar to students, and make cognitive demands on them over and above those needed for solving the type of problems that they would encounter routinely at school, even when the skills needed have been learned. Problems may be mathematical or set in real-life situations, and both involve transfer of knowledge and skills to new situations.

Figure 1.5 and Figure 1.6 show two different Year 4 items which map the *reasoning* cognitive domain; the first is from the *algebra* content domain and the second from the *geometry* content domain. In the first example, students are required to recognise and extrapolate a number pattern, and in the second they are required to correctly visualise a rotated three-dimensional design.

Here is a number pattern.

100, 1, 99, 2, 98, □, □, □

What three numbers should go in the boxes?

● 3, 97, 4

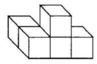
Ⓑ 4, 97, 5

Ⓒ 97, 3, 96

Ⓓ 97, 4, 96

Figure 1.5 Example of Year 4 item for *Reasoning* cognitive domain, *Measurement* content domain

This figure will be turned to a different position.



Which of these could be the figure after it is turned?

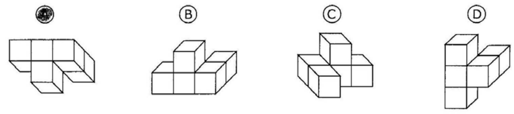
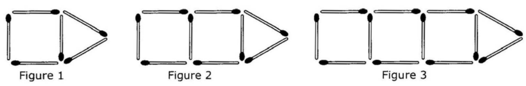


Figure 1.6 Example of Year 4 item for *Reasoning* cognitive domain, *Algebra* content domain

Figure 1.7 and Figure 1.8 show examples of the type of item that map the *reasoning* cognitive domain for Year 8 students. Both require students to use logical reasoning as well as their basic knowledge of patterns and algebra in the first instance, and of fractions and decimals in the second.

Matches are arranged as shown in the figures.



If the pattern is continued, how many matches would be used to make Figure 10?

Ⓐ 30

● 33

Ⓒ 36

Ⓓ 39

Ⓔ 42

Figure 1.7 Example of Year 8 item for *Reasoning* cognitive domain, *Algebra* content domain

Two-thirds of the people present at the beginning of a meeting are men. Nobody leaves but 10 more men and 10 more women arrive at the meeting. Which of the following statements is true?

● There would then be more men than women at the meeting.

Ⓑ There would then be the same number of men as there are women at the meeting.

Ⓒ There would then be more women than men at the meeting.

Ⓓ From the information given, you cannot tell whether there would be more women or men.

Figure 1.8 Example of Year 8 item for *Reasoning* cognitive domain, *Number* content domain

Scaling methodology

The methodology used to create the cognitive domains scales was the same as that used to report the mathematics content scales. Item response theory (IRT) scaling was used to describe student achievement on both cognitive and content domains, and to facilitate comparisons across the domains. The three cognitive domains were set to have the same mean and standard deviation as the overall mathematics scales (i.e., a mean of 467 and a standard deviation of 100 for year 8, and a mean of 495 and a standard deviation of 100 for year 4). The methodology underpinning this scaling is described fully in the *TIMSS 2003 Technical Report* (Martin, Mullis & Chrostowski, 2004).

Is it a significant difference? Standard errors and confidence intervals

In TIMSS, the unknown mean score of the whole population is estimated from the mean score obtained from a sample of students from the population. For this reason, each mean score estimate is accompanied by a statement of the associated error of that estimate. This error, which is labelled the standard error, is an indication that there is some *uncertainty* involved in estimating the characteristics of a population of students by measuring the characteristics of a sample of those students. The accuracy of the estimate provided by the mean score varies according to sample size and to how the sampling was done. Larger standard errors typically result from lower response rates or from differences in sample sizes. In this report, estimates of population parameters (such as mean scores) are often presented with a standard error in parentheses. This means that there is a 95 per cent probability that the true estimate of a population parameter lies within plus or minus 1.96 standard errors of the sample estimate.

For example if a state's mean student performance is 520 with a standard error of 4, then sampling theory indicates that we can be 95 per cent certain that the mean in the population from which the sample was drawn is between 512 (=520 – 1.96x4) and 528 (=520 + 1.96x4). The 95 per cent confidence interval is 512 to 528, meaning that we are 95 per cent certain that the true population mean lies somewhere between 528 and 512.

In making comparisons, for example between states, between males and females, or between Indigenous and non-Indigenous, the confidence intervals can be inspected for overlap. If the confidence intervals do not overlap, we can say that we are 95 per cent certain that the means are significantly different. Similarly, for the difference between two scores to be significant, the difference needs to be more than 1.96 times the standard error.

Sample variation, or error, is the reason that survey research is not useful for producing rankings. For example if the mean for one country can range between 528 and 512, and the mean for a second country can range between 535 and 500, then the rankings could be either way around, depending on the sample taken. There is no definitive 'first' and 'second'.

Overall mathematics achievement

To provide a context for examining Australian students' mathematics achievement in each of the cognitive domains, this report first provides an overview of Australia's overall mathematics achievement in TIMSS 2002/03. Table 1.3 and Table 1.4 present the average scores (and standard errors) in mathematics for all students and for males and females, for each country including Australia and for each of the eight Australian states and territories. At each year level, countries (and states) are shown in decreasing order of average score, together with an indication of whether this average was significantly[2] higher or lower than the international average. Table 1.3 relates to Year 4 students and Table 1.4 to Year 8 students.

To recapitulate the international and national results, reported in full in the national and international reports, Singapore was the highest-performing country in mathematics at both Year 4 and Year 8. The average score for Singaporean students for mathematics overall was 125 scale points, or one and a quarter standard deviations, higher than that of Australian students at Year 4, and one hundred scale points, or one standard deviation, higher for Year 8 students. Australia's

[2] The international averages of 467 at Year 8 and 495 at Year 4 were calculated by averaging the mean scores for each of the participating countries that met the sample requirements. The mean scores for the Australian states separately were not included in these calculations.

overall achievement in mathematics was not significantly different from the international average for Year 4 students, but was significantly higher than the international average for Year 8 students.

Within Australia, there were some differences in mathematics performance by state, and these were reported in the national report: *Summing it up: Mathematics achievement in Australian schools in TIMSS 2002*. The tables of multiple comparisons in mathematics achievement presented in the national report are provided in Appendix A.

At Year 4, students in the Australian Capital Territory were the only students to perform at a level significantly higher than the international average, while those in Western Australia performed at a level significantly lower than the international average. At Year 8, students in New South Wales performed at the highest level, and they and students in the Australian Capital Territory, South Australia, Victoria, Queensland and Western Australia performed significantly better than the international average. Students from Tasmania and the Northern Territory performed at a level not significantly different from the international average.

There were few significant gender differences internationally in overall mathematics performance: within nine of the 25 countries participating at Year 4, and within 18 of the 46 countries that participated at Year 8 level. There was no significant gender difference in Australia overall, and while some of the gender differences within the Australian states appear large, the standard errors are also large, and so none were statistically significant.

Also shown in both Table 1.3 and Table 1.4 is the average age of students. It is the aim in TIMSS that all students assessed would have had four years of formal schooling at Year 4, and eight years of formal schooling at Year 8. While this was the case for most participating countries, there were some variations in policy about the age at which children begin formal schooling[3], and this is evident in the differences in ages of students. Most notably at Year 4 level, some students in the Russian Federation and Slovenia had had as little as three years of formal schooling, while students in England, Scotland, and some parts of Australia and New Zealand, had had five years of formal schooling.

3 Represented by the number of years of formal schooling counting from the first year of ISCED Level 1

Table 1.3 Year 4 mathematics achievement nationally and internationally

Countries / States		Average scale score (se)	Average Age	Yrs school -ing	Girls average scale score		Boys average scale score		Difference (Absolute value)[2]
Singapore	▲	594 (5.6)	10.3	**4**	**599 (5.5)**	▲	**590 (6.2)**		**8 (3.9)**
[1]Hong Kong, SAR	▲	575 (3.2)	10.2	4	575 (3.4)		575 (3.4)		0 (2.3)
Japan	▲	565 (1.6)	10.4	4	563 (1.8)		566 (2.1)		4 (2.3)
Chinese Taipei	▲	564 (1.8)	10.2	4	564 (1.7)		564 (2.1)		1 (1.7)
Belgium (Flemish)	▲	551 (1.8)	10.0	4	549 (1.8)		552 (2.5)		2 (2.5)
[1]Netherlands	▲	540 (2.1)	10.2	4	**537 (2.7)**		**543 (2.2)**	▲	**6 (2.4)**
Latvia	▲	536 (2.8)	11.1	4	536 (2.9)		536 (3.5)		1 (2.9)
[1]Lithuania	▲	534 (2.8)	10.9	4	535 (3.5)		536 (3.2)		1 (2.8)
Russian Federation	▲	532 (4.7)	10.6	3 or 4	530 (5.4)		534 (4.7)		4 (3.5)
[1]England	▲	531 (3.7)	10.3	5	530 (3.9)		532 (4.5)		2 (4.0)
Hungary	▲	529 (3.1)	10.5	4	527 (3.8)		530 (3.3)		3 (3.4)
Australian Capital Territory	▲	*523 (13.7)*	*10.1*	*5*	*504 (13.5)*		*541 (18.5)*		*38 (13.7)*
[1] United States	▲	518 (2.4)	10.2	4	**514 (2.4)**		**522 (2.7)**	▲	**8 (1.6)**
Cyprus	▲	510 (2.4)	9.9	4	**505 (2.7)**		**514 (2.9)**	▲	**9 (2.8)**
New South Wales		*510 (9.2)*	*10.0*	*5*	*514 (9.6)*		*507 (10.0)*		*7 (7)*
Victoria		*508 (6.8)*	*10.1*	*5*	*507 (8.8)*		*508 (7.3)*		*2 (8.4)*
Moldova, Rep. Of		504 (4.9)	11.0	4	510 (5.2)	▲	**499 (5.1)**		**11 (3.5)**
Italy	▲	503 (3.7)	9.8	4	498 (4.1)		**507 (3.7)**	▲	**9 (2.6)**
[1] AUSTRALIA		**499 (3.9)**	**9.9**	**4 or 5**	**497 (4.5)**		**500 (4.3)**		**3 (4.0)**
Tasmania		*497 (13.2)*	*10.2*	*5*	*499 (13.8)*		*489 (12.0)*		*10 (9.7)*
INTERNATIONAL AVERAGE		495 (0.8)	10.3	4	495 (0.8)		496 (0.8)		1 (0.7)
New Zealand		493 (2.2)	10.0	4.5-5.5	493 (2.7)		494 (2.4)		0 (2.9)
[1] Scotland		490 (3.3)	9.7	5	**485 (3.2)**		**496 (4.4)**	▲	**11 (4.1)**
South Australia		*485 (8.3)*	*9.4*	*4*	*481 (9.7)*		*488 (8.0)*		*7 (5.9)*
Queensland		*484 (7.1)*	*9.4*	*4*	*480 (9.4)*		*493 (8.2)*		*13 (10.2)*
Northern Territory		*479 (14.9)*	*9.8*	*4*	*471 (19.7)*		*489 (15.0)*		*18 (18.8)*
Slovenia	▼	479 (2.6)	9.8	3 or 4	477 (3.0)		481 (3.5)		5 (3.8)
Western Australia	▼	*472 (7.8)*	*9.4*	*4*	*465 (7.5)*		*480 (9.1)*		*15 (6.1)*
Armenia	▼	456 (3.5)	10.9	4	462 (3.7)	▲	450 (3.8)		12 (2.9)
Norway	▼	451 (2.3)	9.8	4	449 (2.7)		454 (2.7)		5 (2.8)
Iran, Islamic Rep. of	▼	389 (4.2)	10.4	4	394 (6.5)		386 (5.5)		8 (8.8)
Philippines	▼	358 (7.9)	10.8	4	**364 (9.2)**	▲	**352 (7.0)**		**12 (4.6)**
Morocco	▼	347 (5.1)	11.0	4	344 (6.1)		350 (5.1)		6 (4.7)
Tunisia	▼	339 (4.7)	10.4	4	342 (5.0)		337 (4.9)		5 (2.8)

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

[2] Average scores have been rounded. Differences are calculated from figures that are accurate to two decimal places, so may not be identical to those derived from a simple subtraction of figures in the body of this table.

▲ Score is significantly higher than the International average

▼ Score is significantly lower than the International average

Table 1.4 Year 8 mathematics achievement nationally and internationally

Countries / States		Average scale score (se)	Average Age	Years school-ing	Girls average scale score		Boys average scale score		Difference (Absolute value)
Singapore	▲	605 (3.6)	14.3	8	**611 (3.3)**	▲	**601 (4.3)**		**10 (2.9)**
[1]Korea, Rep. of	▲	589 (2.2)	14.6	8	586 (2.7)		592 (2.6)		5 (3.1)
[1]Hong Kong, SAR	▲	586 (3.3)	14.4	8	587 (3.8)		585 (4.6)		2 (5.1)
Chinese Taipei	▲	585 (4.6)	14.2	8	589 (4.9)		582 (5.2)		7 (4.2)
Japan	▲	570 (2.1)	14.4	8	569 (4.0)		571 (3.6)		3 (6.4)
Belgium (Flemish)	▲	537 (2.8)	14.1	8	532 (3.5)		**542 (3.8)**	▲	**11 (4.8)**
[1]Netherlands	▲	536 (3.8)	14.3	8	533 (4.1)		540 (4.5)		7 (3.6)
Estonia	▲	531 (3.0)	15.2	8	532 (3.4)		530 (3.3)		2 (3.0)
New South Wales	▲	*530 (12.0)*	*14.0*	*9*	*514 (15.4)*		*550 (13.4)*		*36 (18.7)*
Hungary	▲	529 (3.2)	14.5	8	526 (3.7)		**533 (3.5)**	▲	**7 (3.2)**
Malaysia	▲	508 (4.1)	14.3	8	512 (4.7)		505 (4.5)		8 (4.2)
Latvia	▲	508 (3.2)	15.0	8	511 (3.3)		506 (3.7)		6 (2.9)
Russian Federation	▲	508 (3.7)	14.2	7 or 8	510 (3.5)		507 (4.4)		3 (2.8)
Slovak Republic	▲	508 (3.3)	14.3	8	508 (3.4)		508 (4.0)		0 (3.5)
Australian Capital Territory	▲	*507 (9.6)*	*14.1*	*9*	*517 (10.3)*		*495 (9.7)*		*23 (11.6)*
AUSTRALIA	▲	**505 (4.6)**	**13.9**	***8 or 9***	**499 (5.8)**		**511 (5.8)**		**13 (7.0)**
[1]United States	▲	504 (3.3)	14.2	8	502 (3.4)		**507 (3.5)**	▲	**6 (1.9)**
[1]Lithuania	▲	502 (2.5)	14.9	8	503 (2.9)		499 (3.0)		5 (2.9)
South Australia	▲	*501 (11.3)*	*13.8*	*8*	*493 (8.5)*		*511 (16.9)*		*19 (16.3)*
Sweden	▲	499 (2.6)	14.9	8	499 (3.0)		499 (2.7)		1 (2.2)
[1]Scotland	▲	498 (3.7)	13.7	9	500 (4.3)		495 (3.8)		5 (3.5)
England	▲	498 (4.7)	14.3	9	499 (5.3)		498 (5.8)		0 (6.0)
[1]Israel	▲	496 (3.4)	14.0	8	492 (3.3)		500 (4.5)		8 (4.0)
Victoria	▲	*495 (6.4)*	*14.1*	*9*	*496 (6.6)*		*494 (8.1)*		*2 (7.6)*
New Zealand	▲	494 (5.3)	14.1	8.5 – 9.5	495 (4.8)		493 (7.0)		3 (5.7)
Slovenia	▲	493 (2.2)	13.8	7 or 8	495 (2.6)		491 (2.6)		3 (2.8)
Queensland	▲	*490 (6.1)*	*13.4*	*8*	*490 (5.5)*		*491 (9.3)*		*1 (8.6)*
Western Australia	▲	*487 (7.6)*	*13.4*	*8*	*484 (8.2)*		*491 (8.2)*		*7 (7.0)*
Italy	▲	484 (3.2)	13.9	8	481 (3.0)		**486 (3.9)**	▲	**6 (2.8)**
Armenia	▲	478 (3.0)	14.9	8	**483 (3.3)**	▲	473 (3.4)		**10 (3.0)**
Serbia & Montenegro	▲	477 (2.6)	14.9	8	**480 (2.9)**	▲	473 (2.9)		**7 (2.8)**
Tasmania		*477 (12.3)*	*14.2*	*9*	*487 (13.9)*		*468 (12.4)*		*19.7 (11.7)*
Bulgaria	▲	476 (4.3)	14.9	8	476 (5.5)		477 (4.3)		1 (4.7)
Romania		475 (4.8)	15.0	8	477 (5.1)		473 (5.0)		4 (3.3)
INTERNATIONAL AVERAGE		**467 (0.5)**	**14.5**	***8***	**467 (0.6)**		**466 (0.6)**		**1 (0.6)**
Norway	▼	461 (2.5)	13.8	7	463 (2.7)		460 (3.0)		3 (2.8)
Moldova, Rep. Of		460 (4.0)	14.9	8	**465 (4.1)**	▲	**455 (4.8)**		**10 (3.5)**
Cyprus	▼	459 (1.7)	13.8	8	**467 (1.9)**	▲	**452 (2.3)**		**16 (2.7)**
Northern Territory		*449 (14.2)*	*13.8*	*8*	*449 (14.0)*		*451 (14.9)*		*2 (8.2)*
[1]Macedonia, Rep. Of	▼	435 (3.5)	14.6	8	**439 (4.0)**	▲	**431 (3.9)**		**9 (3.5)**
Lebanon	▼	433 (3.1)	14.6	8	**429 (3.6)**		**439 (3.9)**	▲	**10 (4.0)**
Jordan	▼	424 (4.1)	13.9	8	**438 (4.6)**	▲	**411 (5.8)**		**27 (6.8)**
Iran, Islamic Rep. of	▼	411 (2.4)	14.4	8	417 (4.3)		408 (4.2)		9 (7.2)
[1]Indonesia	▼	411 (4.8)	14.5	8	411 (4.9)		410 (5.3)		1 (3.0)
Tunisia	▼	410 (2.2)	14.8	8	**399 (2.6)**		**423 (2.2)**	▲	**24 (1.9)**
Egypt	▼	406 (3.5)	14.4	8	407 (4.4)		406 (5.0)		1 (6.4)
Bahrain	▼	401 (1.7)	14.1	8	**417 (2.4)**	▲	**385 (2.4)**		**33 (3.3)**
Palestinian Nat'l Auth.	▼	390 (3.1)	14.1	8	394 (3.9)		386 (4.7)		8 (5.9)
Chile	▼	387 (3.3)	14.2	8	**379 (3.5)**		**394 (4.3)**	▲	**15 (4.5)**
[1]Morocco	▼	384 (3.8)	15.2	8	**381 (2.8)**		**393 (3.0)**	▲	**12 (3.1)**
Philippines	▼	378 (5.2)	14.8	**8**	**383 (5.2)**	▲	**370 (5.8)**		**13 (3.4)**
Botswana	▼	366 (2.6)	15.1	8	368 (2.6)		365 (2.9)		3 (1.8)
Saudi Arabia	▼	332 (4.6)	14.1	8	326 (7.9)		336 (5.5)		10 (9.7)
Ghana	▼	276 (4.7)	15.5	8	266 (5.1)		283 (4.9)	▲	17 (3.1)
South Africa	▼	264 (5.5)	15.1	8	262 (6.2)		264 (6.4)		3 (5.8)

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

▲ Country's score significantly higher than the International average

▼ Country's score significantly lower than the International average

Similarly at Year 8 level, students in the Russian Federation, Slovenia and Norway had seven years of schooling, while some of those in Australia, New Zealand, Scotland and England had had nine years of formal schooling. Within Australia, students in Western Australia, Northern Territory, South Australia and Queensland generally had one less year of formal schooling than their counterparts in other states.

The national report on mathematics achievement (Thomson & Fleming, 2004a, see Appendix A of this report for multiple comparison tables) showed that at Year 4 level, there were few differences in overall mathematics achievement between states, with the only significant differences being that students in the Australian Capital Territory, New South Wales and Victoria significantly outperformed students in Western Australia, on average.

At Year 8 level, there were again only a handful of differences: students in New South Wales outperformed those in Queensland, Western Australia and the Northern Territory, and students in the Australian Capital Territory outperformed those in the Northern Territory.

2. Achievement in the Cognitive Domains

This chapter of the report presents the mathematics achievement results for each of the three cognitive domains in the TIMSS 2002 study. International results are also presented in this section.

Knowing

As has been previously stated, facility in using mathematics, or reasoning about mathematical situations, depends to a large extent on the student's mathematical knowledge and familiarity with mathematical concepts. The greater the student's automatic recall of facts, procedures and concepts, the greater the ability to make extensions beyond their existing knowledge and to apply their skills to more complex problems. The TIMSS 2003 Assessment Frameworks (Mullis et al, 2003) elaborates this cognitive domain as shown in Figure 2.1 below:

Figure 2.1 KNOWING FACTS, PROCEDURES, AND CONCEPTS

Without access to a knowledge base that enables easy recall of the language and basic facts and conventions of number, symbolic representation, and spatial relations, students would find purposeful mathematical thinking impossible. Facts encompass the factual knowledge that provides the basic language of mathematics, and the essential mathematical facts and properties that form the foundation for mathematical thought.

Procedures form a bridge between more basic knowledge and the use of mathematics for solving routine problems, especially those encountered by many people in their daily lives. In essence a fluent use of procedures entails recall of sets of actions and how to carry them out. Students need to be efficient and accurate in using a variety of computational procedures and tools. They need to see that particular procedures can be used to solve entire classes of problems, not just individual problems. Knowledge of concepts enables students to make connections between elements of knowledge that, at best, would otherwise be retained as isolated facts. It allows them to make extensions beyond their existing knowledge, judge the validity of mathematical statements and methods, and create mathematical representations.

This cognitive domain covers the following behaviours:

1. **Recall**	Recall definitions; terminology; number properties; geometric properties; and notation (e.g., $a \times b = ab$, $a + a + a = 3a$).
2. **Recognize**	Recognize mathematical objects, shapes, numbers and expressions. Recognize mathematical entities that are mathematically equivalent (e.g., equivalent familiar fractions, decimals and percents; different orientations of simple geometric figures).
3. **Compute**	Carry out algorithmic procedures for $+,-,\times,\div$, or a combination of these with whole numbers, fractions, decimals and integers. Approximate numbers to estimate computations. Carry out routine algebraic procedures.
4. **Retrieve**	Retrieve information from graphs, tables or other sources; read simple scales.
5. **Measure**	Use measuring instruments; use units of measurement appropriately; and estimate measures.
6. **Classify/Order**	Classify/group objects, shapes, numbers and expressions according to common properties; make correct decisions about class membership; and order numbers and objects by attributes.

Table 2.1 presents the average scale scores of students' mathematics achievement, and the average scores for males and females separately, as well as the absolute value of the differences, in the *knowing* cognitive domain for the 25 countries that participated in TIMSS 2003 at Year 4 level.

Table 2.2 presents data for the 46 countries that participated at Year 8. Countries are arranged in decreasing order of their average score on this domain, and each is annotated with an indication of whether the country average is higher or lower than the international average. A further annotation indicates whether females' scores were significantly higher than males' scores or vice versa. As a basis for comparison, the international average across all countries was scaled to be the same as the international average for overall mathematics achievement (495 for Year 4 and 467 for Year 8). Also included in these tables are the scores for each of the states of Australia.

A comparison of these results with the results in overall mathematics indicates that there is a strong link between countries' performance in this domain and in overall mathematics performance in the content domains. Australian students' performance was not statistically different from the international average at Year 4 level, but significantly higher than the international average at Year 8 level.

Table 2.1 Average mathematics achievement overall and by gender for *Knowing* cognitive domain, Year 4

Countries / States		Average scale score (se)	Girls average scale score		Boys average scale score		Difference (Absolute value)[2]
Singapore	▲	**626 (6.5)**	**632 (6.4)**	⬆	**620 (7.2)**		**11 (4.5)**
Hong Kong, SAR	▲	574 (3.3)	574 (3.9)		573 (3.6)		1 (3.5)
Chinese Taipei	▲	565 (2.2)	564 (2.4)		566 (2.6)		2 (2.3)
Japan	▲	564 (2.1)	565 (2.6)		564 (3.0)		2 (3.7)
Belgium (Flemish)	▲	558 (2.1)	556 (2.6)		560 (2.9)		4 (3.5)
England	▲	534 (4.5)	534 (4.4)		534 (5.3)		0 (3.7)
Netherlands	▲	530 (2.2)	527 (3.0)		533 (2.6)		6 (3.5)
United States	▲	**528 (2.5)**	**525 (2.4)**		**532 (3.0)**	⇧	**7 (2.3)**
Australian Capital Territory	▲	*525 (13.2)*	*508 (13.2)*		*542 (18.5)*		*34 (21.3)*
Lithuania	▲	519 (2.7)	522 (3.3)		520 (3.6)		2 (3.6)
Hungary	▲	517 (3.3)	516 (4.1)		518 (3.6)		2 (4.0)
Latvia	▲	517 (2.9)	518 (3.1)		515 (3.5)		3 (3.5)
Italy	▲	**514 (3.9)**	**510 (4.3)**		**518 (4.1)**	⇧	**8 (3.0)**
Russian Federation		513 (5.3)	513 (5.8)		514 (5.8)		1 (4.6)
New South Wales		*512 (9.5)*	*518 (8.5)*		*508 (11.7)*		*10 (8.2)*
Victoria		*508 (6.0)*	*508 (7.9)*		*509 (6.4)*		*1 (7.8)*
AUSTRALIA		501 (3.8)	501 (4.1)		502 (4.6)		1 (4.1)
Moldova, Rep. Of		**500 (5.2)**	**507 (5.9)**	⬆	**495 (5.3)**		**12 (4.1)**
Cyprus		**500 (2.8)**	**496 (3.1)**		**504 (3.6)**	⇧	**8 (3.6)**
Tasmania		*498 (12.9)*	*500(14.0)*		*492 (11.5)*		*8 (8.7)*
INTERNATIONAL AVERAGE		495 (0.7)	496 (0.9)		495 (0.9)		0 (0.9)
New Zealand		493 (2.2)	494 (2.9)		492 (2.5)		2 (3.2)
South Australia		*490 (7.8)*	*488 (8.0)*		*491 (8.9)*		*3 (6.5)*
Queensland		*486 (6.7)*	*483 (9.7)*		*494 (6.3)*		*11 (9.1)*
Scotland	▼	**484 (3.0)**	**478 (3.1)**		**489 (4.2)**	⇧	**11 (4.2)**
Northern Territory		*482 (13.0)*	*477 (18.9)*		*489 (12.7)*		*12 (19.9)*
Western Australia	▼	*477 (7.7)*	*471 (7.6)*		*484 (8.7)*		*13 (6.3)*
Slovenia	▼	470 (2.6)	469 (3.1)		471 (3.3)		2 (3.7)
Norway	▼	448 (2.1)	447 (2.5)		449 (3.1)		2 (3.7)
Armenia	▼	**447 (3.7)**	**455 (3.7)**	⬆	**439 (4.3)**		**16 (3.3)**
Iran, Islamic Rep. of	▼	404 (4.0)	411 (6.6)		399 (4.5)		12 (7.7)
Philippines	▼	**385 (6.9)**	**389 (8.0)**	⬆	**380 (6.3)**		**9 (4.4)**
Morocco	▼	360 (4.4)	356 (5.6)		363 (4.3)		7 (4.7)
Tunisia	▼	338 (4.2)	337 (4.8)		338 (4.6)		1 (3.8)

▲ Country's score significantly higher than the International average
▼ Country's score significantly lower than the International average
⬆ Female score significantly higher than male score
⇧ Male score significantly higher than female score

Scoring at a significantly higher level than Australia[4] in the *knowing* cognitive domain at Year 4 level were 12 countries - Singapore, Hong Kong, Chinese Taipei, Japan, Belgium (Flemish), England, the Netherlands, the United States, Lithuania, Hungary, Latvia and Italy. Australian students' average score was 125 scale points (one and a quarter standard deviations) lower than the average for students in Singapore. Australia's scores in this domain at Year 4 were not significantly different from those of the Russian Federation, Republic of Moldova, Cyprus and New Zealand, and were significantly higher than those below this in Figure 2.1, including Scotland.

For Year 4, gender differences were apparent in eight of the countries, with males scoring higher in the United States, Italy, Cyprus and Scotland, and females scoring higher in Singapore, the Republic of Moldova, Armenia and the Philippines. In Australia there were no gender differences apparent overall or in any state.

The data for students in Year 8 are provided in Table 2.2. The top four performing countries at this year level in the *knowing* cognitive domain were the Republic of Korea, Singapore, Hong Kong and Chinese Taipei, followed closely by Japan. Australia, while performing at a level significantly higher than the international average, performed at a significantly lower level than these countries (and on average 95 scale points – almost one standard deviation - lower than the average for students in the Republic of Korea), and also Estonia, Belgium (Flemish), Hungary, the Netherlands, the Russian Federation, Latvia, Slovak Republic, Lithuania and the United States. Australian students' performance was statistically similar to that of students in Malaysia, Israel, Slovenia, Serbia, England, Bulgaria, Romania and New Zealand, and significantly higher than that of students in Sweden and all other countries from Italy through to Ghana, including Scotland.

Gender differences at Year 8 largely favoured females. Internationally and in 17 individual countries, females scored at a significantly higher level than males, while only in four countries did males significantly outperform females. In Australia there were no gender differences apparent overall or in any state.

4 Interpreted from the multiple comparisons tables provided in the International Report

Table 2.2 Average mathematics achievement overall and by gender for *Knowing* cognitive domain, Year 8

Countries / States		Average scale score (se)	Girls average scale score		Boys average scale score		Difference (Absolute value)
Korea, Rep. of	▲	592 (2.1)	589 (2.9)		594 (2.4)		5 (3.2)
Singapore	▲	**591 (3.1)**	**596 (2.9)**	↑	**586 (3.7)**		**10 (2.6)**
Hong Kong, SAR	▲	589 (3.3)	591 (3.7)		587 (4.6)		4 (5.2)
Chinese Taipei	▲	585 (4.5)	589 (5.0)		582 (5.0)		7 (4.3)
Japan	▲	564 (1.9)	564 (3.8)		564 (3.4)		1 (6.1)
Estonia	▲	538 (2.7)	538 (3.2)		538 (3.0)		1 (2.9)
Belgium (Flemish)	▲	537 (2.5)	534 (3.4)		541 (3.6)		7 (4.8)
Hungary	▲	536 (3.1)	537 (3.6)		536 (3.4)		1 (3.2)
New South Wales	▲	*521 (10.3)*	*507 (13.2)*		*539 (12.1)*		*32 (16.4)*
Netherlands	▲	520 (3.1)	518 (3.5)		522 (3.6)		4 (3.3)
Russian Federation	▲	**519 (3.4)**	**525 (3.5)**	↑	**514 (3.7)**		**11 (2.5)**
Latvia	▲	**518 (2.8)**	**523 (2.9)**	↑	**514 (3.4)**		**10 (3.0)**
Slovak Republic	▲	**517 (3.3)**	**521 (3.4)**	↑	**514 (3.9)**		**7 (3.2)**
Lithuania	▲	**511 (2.7)**	**514 (3.5)**	↑	**507 (2.9)**		**8 (3.3)**
United States	▲	**510 (2.8)**	**508 (3.0)**		**512 (3.0)**	⇧	**4 (2.0)**
Malaysia	▲	**506 (3.9)**	**511 (4.4)**	↑	**501 (4.4)**		**11 (4.2)**
Israel	▲	501 (3.1)	499 (3.3)		503 (4.0)		4 (3.9)
Slovenia	▲	**499 (2.2)**	**502 (2.6)**	↑	**495 (2.9)**		**7 (3.5)**
Australian Capital Territory	▲	*498 (9.4)*	*508 (10.4)*		*487 (8.6)*		*21 (10.3)*
AUSTRALIA	▲	497 (4.0)	491 (5.1)		502 (5.2)		11 (6.4)
Serbia	▲	**495 (2.7)**	**502 (3.1)**	↑	**489 (3.1)**		**13 (3.2)**
South Australia	▲	*492 (9.4)*	*486 (6.8)*		*499 (14.4)*		*14 (14.1)*
England	▲	489 (4.0)	488 (4.5)		489 (5.2)		1 (5.6)
Victoria	▲	*488 (6.0)*	*489 (6.4)*		*488 (7.4)*		*1 (6.9)*
Sweden	▲	486 (2.1)	486 (2.5)		486 (2.3)		0 (2.0)
Bulgaria	▲	486 (4.1)	487 (5.0)		484 (4.3)		3 (4.5)
Romania	▲	**485 (4.9)**	**489 (5.3)**	↑	**481 (5.2)**		**8 (3.6)**
New Zealand	▲	485 (4.8)	484 (4.3)		486 (6.5)		2 (5.3)
Italy	▲	484 (3.2)	483 (3.2)		485 (3.8)		3 (2.8)
Queensland	▲	*483 (4.7)*	*483 (4.4)*		*483 (7.2)*		*0 (6.9)*
Scotland	▲	481 (3.2)	483 (3.9)		478 (3.4)		4 (3.4)
Armenia	▲	**480 (2.9)**	**486 (3.2)**	↑	**474 (3.4)**		**13 (3.2)**
Western Australia		*479 (6.3)*	*476 (6.3)*		*483 (6.8)*		*7 (5.1)*
Tasmania		*471 (11.0)*	*480 (12.1)*		*464 (11.4)*		*17 (9.6)*
INTERNATIONAL AVG.		**467 (0.5)**	**468 (0.6)**	↑	**465 (0.6)**		**3 (0.7)**
Moldova, Rep. of		**466 (4.1)**	**472 (4.9)**	↑	**460 (4.6)**		**12 (4.7)**
Cyprus		**466 (2.0)**	**474 (2.1)**	↑	**458 (2.6)**		**16 (2.6)**
Norway	▼	450 (2.1)	451 (2.5)		449 (3.0)		2 (3.5)
Lebanon	▼	447 (3.2)	444 (3.6)		452 (3.9)		8 (4.0)
Macedonia, Rep. of	▼	**447 (3.8)**	**452 (4.1)**	↑	**442 (4.2)**		**10 (3.3)**
Northern Territory	▼	*444 (9.6)*	*444 (10.9)*		*447 (9.0)*		*3 (8.5)*
Jordan	▼	**428 (4.7)**	**442 (5.5)**	↑	**415 (6.2)**		**26 (7.2)**
Indonesia	▼	422 (4.3)	423 (4.5)		421 (4.6)		2 (3.4)
Egypt	▼	411 (3.4)	413 (4.1)		409 (4.8)		4 (6.0)
Iran, Islamic Rep. of	▼	405 (2.6)	412 (4.8)		401 (4.2)		11 (7.3)
Bahrain	▼	**401 (2.3)**	**419 (2.8)**	↑	**383 (3.2)**		**36 (4.0)**
Tunisia	▼	**399 (3.0)**	**388 (3.6)**		**410 (3.0)**	⇧	**22 (2.8)**
Palestinian Nat'l Auth.	▼	**391 (3.7)**	**398 (4.8)**	↑	**382 (5.6)**		**17 (7.3)**
Philippines	▼	**388 (5.2)**	**395 (5.2)**	↑	**379 (6.1)**		**15 (4.4)**
Chile	▼	**386 (3.2)**	**378 (3.5)**		**393 (4.1)**	⇧	**15 (4.5)**
Morocco	▼	386 (2.8)	383 (3.7)		392 (4.2)		8 (5.4)
Botswana	▼	372 (2.8)	374 (3.0)		370 (3.6)		4 (3.3)
Saudi Arabia	▼	315 (4.6)	309 (6.9)		319 (6.2)		10 (9.5)
South Africa	▼	261 (5.4)	260 (6.1)		261 (6.3)		1 (5.8)
Ghana	▼	**232 (5.9)**	**220 (7.0)**		**243 (6.4)**	⇧	**23 (6.1)**

▲ Country's score significantly higher than the International average
▼ Country's score significantly lower than the International average
↑ Female score significantly higher than male score
⇧ Male score significantly higher than female score

State differences

This section of this report looks in more detail at achievement in the *knowing* cognitive domain within Australia. Table 2.3 provides multiple comparisons for each state's average achievement at Year 4 in the *knowing* domain compared to achievement in the other states. It should be noted that as standard errors are quite large, particularly in the smaller states, there are not a lot of differences that are statistically significant. Significant differences were found between students in the lowest scoring state on the *knowing* domain, Western Australia, and students in the ACT, scoring 48 scale points (almost half a standard deviation) higher, and students in Victoria, scoring 30 score points higher. Although this is perhaps not surprising as students in Western Australia are generally younger than those in ACT and Victoria, students in Queensland, South Australia and Northern Territory are in a similar position with regards to age of students and yet their level of knowledge is not significantly different from that of students in states where the cohort is older.

Table 2.3 Multiple comparisons of states' mathematics achievement for *Knowing* cognitive domain, Year 4

State	Mean	SE	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	512	9.5	●	●	●	●	●	●	●
VIC	508	6.0		●	●	▲	●	●	●
QLD	486	6.7	●		●	●	●	●	●
SA	490	7.8	●	●		●	●	●	●
WA	477	7.7	▼	●	●		●	●	▼
TAS	498	12.9	●	●	●	●		●	●
NT	482	13.0	●	●	●	●	●		●
ACT	525	13.2	●	●	●	▲	●	●	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state

Table 2.4 provides multiple comparisons for the Australian states for Year 8 in the *knowing* cognitive domain. This shows that Year 8 students in New South Wales achieved at a significantly higher level in the *knowing* cognitive domain than their counterparts in all states other than the ACT, while those in the Northern Territory were outperformed by students in all states other than Tasmania. All other differences were non-significant.

Table 2.4 Multiple comparisons of states' mathematics achievement for *Knowing* cognitive domain, Year 8

State	Mean	SE	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	521	10.3	▲	▲	▲	▲	▲	▲	●
VIC	488	6.0		●	●	●	●	▲	●
QLD	483	4.7	●		●	●	●	▲	●
SA	492	9.4	●	●		●	●	▲	●
WA	479	6.3	●	●	●		●	▲	●
TAS	471	11.0	●	●	●	●		●	●
NT	444	9.6	▼	▼	▼	▼	●		▼
ACT	498	9.4	●	●	●	●	●	▲	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state

The range in mean scores across states was greater for students at this year level than for Year 4 students, with students in New South Wales scoring, on average, 77 scale points, or three-quarters of a standard deviation, higher than those in the Northern Territory.

Applying

The second cognitive domain defined in the TIMSS Frameworks focuses on the ability of the students to apply their knowledge and conceptual understanding to solve problems or answer questions. The TIMSS 2003 Assessment Frameworks (Mullis et al., p. 34) provides the elaboration of the *applying* domain shown in Figure 2.2.

Figure 2.2 APPLYING KNOWLEDGE AND CONCEPTUAL UNDERSTANDING

Problem solving is a central aim and often a means of teaching school mathematics, and hence this and supporting skills (e.g., select, represent, model) feature prominently in the domain of *applying knowledge and conceptual understanding*. In items aligned with this domain, students need to apply mathematical knowledge of facts, skills, and procedures or understanding of mathematical concepts to create representations and solve problems. Representation of ideas forms the core of mathematical thinking and communication, and the ability to create equivalent representations are fundamental to success in the subject.

The problem settings are more routine than those aligned with the reasoning domain. The routine problems will typically have been standard in classroom exercises designed to provide practice in particular methods or techniques. Some of these problems will have been in words that set the problem situation in a quasi-real context. Though they range in difficulty, each of these types of "textbook" problems is expected to be sufficiently familiar to students that they will essentially involve selecting and applying learned procedures.

Problems may be set in real-life situations, or may be concerned with purely mathematical questions involving, for example, numeric or algebraic expressions, functions, equations, geometric figures, or statistical data sets. Therefore, problem solving is included not only in the applying domain, with emphasis on the more familiar and routine tasks but also in the reasoning, domain. This cognitive domain covers the following behaviours:

1. **Select**	Select an efficient/appropriate operation, method or strategy for solving problems where there is a known algorithm or method of solution.
2. **Represent**	Display mathematical information and data in diagrams, tables, charts, or graphs, and generate equivalent representations for a given mathematical entity or relationship.
3. **Model**	Generate an appropriate model, such as an equation or diagram for solving a routine problem.
4. **Implement**	Follow and execute a set of mathematical instructions. Given specifications, draw figures and shapes.
5. **Solve Routine Problems**	Solve routine problems (i.e., problems similar to those target students are likely to have encountered in class). For example, use geometric properties to solve problems. Compare and match different representations of data (eighth grade) and use data from charts, tables, graphs, and maps to solve routine problems.

Table 2.5 shows that Australian students' performance at Year 4 level in the *applying* cognitive domain was not significantly different from the international average. It was significantly lower than that of students in the higher achieving countries: Singapore, Hong Kong, Japan and Chinese Taipei in particular, and also other countries that outperformed Australia in overall mathematics achievement in TIMSS 2002, including England and the United States. The difference between the Australian average score and that of Singapore was a little more than one standard deviation.

The average scores for students in South Australia, Queensland and Western Australia were significantly lower than the international average; for other states the average score was not significantly different from the international average.

Gender differences were evident in a number of countries. Females scored better, on average, in Singapore, the Republic of Moldova, Armenia and the Philippines, while males outscored females on average internationally, and in Scotland, Italy, the United States, Cyprus, the Netherlands, and Japan. There were no gender differences apparent in Australia overall, or in any state other than Western Australia, where males outscored females by an average of 17 points.

Table 2.5 Average mathematics achievement overall and by gender for *Applying* cognitive domain, Year 4

Countries / States		Average scale score (se)	Girls average scale score		Boys average scale score		Difference (Absolute value)
Singapore	▲	**595 (5.9)**	**599 (5.8)**	⬆	**590 (6.6)**		**9 (4.1)**
Hong Kong, SAR	▲	577 (3.3)	576 (3.5)		577 (3.5)		0 (2.6)
Japan	▲	**566 (2.1)**	**563 (2.6)**		**569 (2.3)**	⇧	**5 (2.5)**
Chinese Taipei	▲	561 (1.9)	561 (2.0)		562 (2.2)		1 (2.0)
Belgium (Flemish)	▲	546 (2.1)	544 (2.5)		548 (2.7)		4 (3.0)
Latvia	▲	545 (3.3)	545 (3.4)		546 (4.0)		1 (3.4)
Russian Federation	▲	542 (4.7)	539 (5.0)		545 (5.1)		6 (3.8)
Lithuania	▲	542 (2.9)	541 (3.7)		545 (3.7)		4 (3.7)
Netherlands	▲	**541 (2.6)**	**538 (2.8)**		**545 (3.2)**	⇧	**7 (3.1)**
Hungary	▲	530 (3.4)	530 (4.0)		531 (3.7)		2 (3.7)
England	▲	526 (4.1)	524 (4.1)		528 (4.9)		4 (4.0)
Australian Capital Territory		514 (14.7)	495 (14.2)		533 (19.6)		38 (21.2)
Cyprus	▲	**510 (2.8)**	**504 (3.1)**		**516 (2.9)**	⇧	**12 (2.4)**
Moldova, Rep. of	▲	**507 (4.8)**	**511 (5.3)**	⬆	**502 (5.0)**		**9 (3.6)**
United States	▲	**505 (2.6)**	**501 (2.8)**		**510 (2.9)**	⇧	**9 (2.1)**
New South Wales		503 (9.1)	506 (8.9)		500 (10.9)		5 (8.3)
Victoria		498 (7.1)	497 (9.5)		499 (6.7)		2 (8.2)
INTERNATIONAL AVG.		**495 (0.7)**	**494 (0.8)**		**497 (0.8)**	⇧	**2 (0.8)**
Italy		**494 (3.6)**	**489 (4.3)**		**498 (3.5)**	⇧	**8 (3.0)**
AUSTRALIA		490 (3.8)	487 (4.3)		492 (4.4)		5 (3.9)
Scotland	▼	**487 (3.5)**	**482 (3.6)**		**492 (4.6)**	⇧	**11 (4.3)**
New Zealand	▼	486 (2.3)	485 (3.0)		486 (2.5)		1 (3.2)
Tasmania		486 (13.5)	487 (14.6)		480 (11.3)		7 (9.3)
Slovenia	▼	477 (2.8)	474 (3.1)		481 (3.8)		7 (4.2)
South Australia	▼	474 (8.1)	471 (8.9)		477 (8.5)		6 (6.1)
Queensland	▼	473 (7.3)	467 (9.8)		483 (7.3)		16 (8.6)
Northern Territory		473 (12.2)	467 (17.9)		479 (11.3)		12 (17.9)
Western Australia	▼	**463 (6.5)**	**455 (6.2)**		**472 (7.8)**	⇧	**17 (6.0)**
Armenia	▼	**462 (3.2)**	**465 (3.2)**	⬆	**459 (3.7)**		**6 (2.8)**
Norway	▼	446 (2.2)	443 (2.8)		449 (3.0)		6 (3.8)
Iran, Islamic Rep. of	▼	391 (3.8)	391 (6.1)		391 (4.8)		0 (7.9)
Philippines	▼	**364 (7.5)**	**370 (8.8)**	⬆	**357 (6.7)**		**13 (4.8)**
Morocco	▼	349 (4.5)	345 (5.6)		352 (4.4)		7 (4.5)
Tunisia	▼	348 (4.6)	351 (5.1)		346 (4.7)		6 (3.6)

▲ Country's score significantly higher than the International average
▼ Country's score significantly lower than the International average
⬆ Female score significantly higher than male score
⇧ Male score significantly higher than female score

Australian students' average score in the *applying* cognitive domain at Year 8 level was significantly higher than the international average, as shown in Table 2.6. Year 8 students significantly outperformed and were significantly outperformed by the same groups of countries for this domain as they were in overall mathematics achievement. Countries which did significantly better than Australia were primarily the Asian countries: Singapore, Hong Kong, Republic of Korea, Chinese Taipei, and Japan. The average score for students in Singapore was slightly more than one standard deviation higher than the average score for Australian students. Those countries whose average performance was not significantly different from that of Australia included Malaysia, Scotland, the United States, and New Zealand.

Students in New South Wales, the Australian Capital Territory, South Australia, Victoria, Queensland and Western Australia performed at a higher level than the international average, while those students in Northern Territory and Tasmania performed at a similar level to the international average.

Table 2.6 Average mathematics achievement overall and by gender for *Applying* cognitive domain, Year 8

Countries / States		Average scale score (se)	Girls average scale score		Boys average scale score		Difference (Absolute value)
Singapore	▲	**611 (3.6)**	**617 (3.6)**	↑	**606 (4.1)**		**11 (3.1)**
Hong Kong, SAR	▲	584 (3.2)	584 (3.7)		584 (4.5)		1 (5.1)
Korea, Rep. of	▲	**584 (2.2)**	**581 (2.9)**		**587 (2.3)**	⇧	**6 (2.9)**
Chinese Taipei	▲	582 (4.6)	584 (5.1)		580 (5.1)		4 (4.2)
Japan	▲	564 (2.2)	563 (4.4)		565 (3.6)		2 (6.7)
Netherlands	▲	**543 (3.7)**	**538 (4.0)**		**548 (4.3)**	⇧	**10 (3.8)**
Belgium (Flemish)	▲	**536 (2.7)**	**529 (3.3)**		**544 (3.7)**	⇧	**15 (4.6)**
New South Wales	▲	535 (12.3)	517 (16.2)		557 (13.8)		40 (19.8)
Estonia	▲	528 (2.9)	531 (3.3)		526 (3.2)		4 (2.9)
Hungary	▲	**523 (3.4)**	**517 (3.8)**		**529 (4.0)**	⇧	**11 (3.5)**
Malaysia	▲	512 (4.4)	515 (5.1)		508 (4.8)		7 (4.6)
AUSTRALIA	▲	**508 (4.8)**	**501 (6.1)**		**516 (6.0)**	⇧	**15 (7.5)**
Australian Capital Territory	▲	508 (11.6)	519 (13.8)		497 (11.0)		22 (14.9)
Scotland	▲	505 (3.9)	506 (4.8)		504 (3.8)		3 (3.8)
Sweden	▲	505 (2.8)	504 (3.2)		506 (2.8)		1 (2.2)
South Australia	▲	505 (11.6)	497 (9.1)		514 (17.6)		17 (17.3)
Latvia	▲	504 (3.4)	505 (3.5)		504 (4.1)		2 (3.4)
England	▲	503 (4.8)	503 (5.4)		504 (6.0)		1 (6.3)
Russian Federation	▲	503 (3.7)	503 (3.8)		503 (4.1)		0 (2.6)
Slovak Republic	▲	502 (3.7)	499 (4.0)		505 (4.3)		6 (3.6)
United States	▲	**502 (3.4)**	**497 (3.5)**		**506 (3.5)**	⇧	**9 (2.1)**
Lithuania	▲	499 (2.8)	499 (3.2)		497 (3.3)		2 (2.9)
New Zealand	▲	497 (5.3)	496 (4.7)		497 (7.2)		1 (5.9)
Victoria	▲	497 (7.4)	498 (8.2)		498 (9.2)		1 (8.9)
Israel	▲	**495 (3.6)**	**490 (3.7)**		**500 (4.6)**	⇧	**10 (4.2)**
Queensland	▲	494 (5.9)	494 (5.8)		496 (8.9)		2 (8.9)
Slovenia	▲	491 (2.3)	491 (3.0)		491 (2.8)		0 (3.6)
Western Australia	▲	489 (8.1)	484 (8.7)		494 (8.3)		10 (7.1)
Italy	▲	**484 (3.2)**	**479 (3.0)**		**488 (4.0)**	⇧	**8 (3.0)**
Tasmania		482 (13.4)	491 (14.3)		473 (14.6)		17 (17.3)
Armenia	▲	**478 (3.0)**	**482 (3.5)**	↑	**473 (3.5)**		**8 (3.6)**
Romania		475 (5.0)	475 (5.4)		474 (5.3)		1 (3.9)
Bulgaria		471 (4.7)	471 (6.0)		472 (4.9)		1 (5.5)
Norway		468 (2.7)	469 (2.8)		468 (3.4)		0 (3.2)
Serbia		467 (2.9)	468 (3.5)		466 (3.1)		3 (2.9)
INTERNATIONAL AVG.		467 (0.5)	466 (0.6)		467 (0.6)		1 (0.6)
Moldova, Rep. of	▼	**457 (3.9)**	**462 (4.0)**	↑	**453 (4.5)**		**9 (3.3)**
Northern Territory		448 (12.7)	446 (14.4)		453 (11.4)		27 (20.2)
Cyprus	▼	**457 (1.6)**	**465 (1.9)**	↑	**450 (2.5)**		**16 (3.1)**
Macedonia, Rep. of	▼	428 (3.8)	431 (4.2)		426 (4.3)		6 (3.9)
Lebanon	▼	**426 (3.3)**	**422 (3.7)**		**432 (4.2)**	⇧	**10 (4.0)**
Jordan	▼	**422 (4.2)**	**436 (4.9)**	↑	**409 (5.8)**		**27 (6.9)**
Tunisia	▼	**419 (2.3)**	**407 (2.6)**		**433 (2.4)**	⇧	**26 (2.1)**
Iran, Islamic Rep. of	▼	416 (2.5)	420 (4.6)		413 (4.1)		7 (7.2)
Indonesia	▼	408 (4.9)	408 (5.0)		409 (5.3)		1 (3.3)
Egypt	▼	404 (3.4)	401 (4.3)		406 (4.9)		5 (6.3)
Bahrain	▼	**398 (1.6)**	**411 (2.3)**	↑	**384 (2.3)**		**27 (3.2)**
Chile	▼	**391 (3.3)**	**382 (3.6)**		**399 (4.2)**	⇧	**18 (4.6)**
Palestinian Nat'l Auth.	▼	388 (3.2)	389 (4.1)		388 (4.6)		1 (5.8)
Morocco	▼	**384 (2.9)**	**377 (3.4)**		**393 (3.3)**	⇧	**16 (3.4)**
Philippines	▼	**378 (4.8)**	**383 (4.8)**	↑	**373 (5.5)**		**10 (3.5)**
Botswana	▼	369 (2.7)	370 (3.0)		368 (2.9)		2 (2.4)
Saudi Arabia	▼	338 (3.6)	332 (6.1)		344 (4.5)		12 (7.9)
Ghana	▼	**293 (4.0)**	**286 (4.9)**		**299 (4.8)**	⇧	**13 (5.2)**
South Africa	▼	269 (5.3)	267 (5.9)		271 (6.5)		3 (6.1)

▲ Country's score significantly higher than the International average
▼ Country's score significantly lower than the International average
↑ Female score significantly higher than male score
⇧ Male score significantly higher than female score

Gender differences were found in the *applying* cognitive domain in 20 of the countries that participated in Year 8. Only in seven of these was the gender difference found to be in favour of females. In the remaining 13 countries, the difference was in favour of males. Within Australia, gender differences were not apparent in any state, but overall, males significantly outperformed females in this cognitive domain.

State differences

The next section of this report looks in more detail at achievement in the *applying* cognitive domain within Australia. Table 2.7 presents the results of multiple comparisons between the states for the Year 4 *applying* cognitive domain. The spread of average scores across the states was again wide, with students in the ACT scoring 51 scale points, or half a standard deviation, higher than those in Western Australia.

Students in New South Wales, Victoria and the Australian Capital Territory performed at a level significantly higher than students in Queensland, Western Australia and South Australia, and students in the ACT also outperformed those in the Northern Territory. All other differences were non-significant.

Table 2.7 Multiple comparisons of states' mathematics achievement for *Applying* cognitive domain, Year 4

State	Mean	SE	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	503	9.1	●	▲	▲	▲	●	●	●
VIC	498	7.1		▲	▲	▲	●	●	●
QLD	473	7.3	▼		●	●	●	●	▼
SA	474	8.1	▼	●		●	●	●	▼
WA	463	6.5	▼	●	●		●	●	▼
TAS	486	13.5	●	●	●	●		●	●
NT	473	12.2	●	●	●	●	●		▼
ACT	514	14.7	●	▲	▲	▲	●	▲	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state

From Table 2.8, it is apparent that students in Year 8 in New South Wales significantly outperformed students in Victoria, Queensland, Western Australia, Tasmania and the Northern Territory. In contrast, students in the Northern Territory were outperformed by all those in all mainland states.

The gap between the highest and lowest scoring states (New South Wales and the Northern Territory respectively) in the *applying* cognitive domain was 87 scale points; almost a whole standard deviation difference.

Table 2.8 Multiple comparisons of states' mathematics achievement for *Applying* cognitive domain, Year 8

State	Mean	SE	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	535	12.3	▲	▲	●	▲	▲	▲	●
VIC	497	7.5		●	●	●	●	▲	●
QLD	494	5.9	●		●	●	●	▲	●
SA	505	11.6	●	●		●	●	▲	●
WA	489	8.1	●	●	●		●	▲	●
TAS	481	13.4	●	●	●	●		●	●
NT	448	12.7	▼	▼	▼	▼	●		▼
ACT	508	11.6	●	●	●	●	●	▲	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state

Reasoning

The *reasoning* domain takes students beyond the solution of routine problems and tests their ability to solve problems which may be set in unfamiliar situations, or complex contexts, or involve multi-step problems. The TIMSS 2003 Assessment Frameworks (Mullis et al., 2003) elaborates the *reasoning* cognitive domain:

Figure 2.3 REASONING

Reasoning mathematically involves the capacity for logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems. Non-routine problems are problems that are very likely to be unfamiliar to students. They make cognitive demands over and above those needed for solution of routine problems, even when the knowledge and skills required for their solution have been learned.

Non-routine problems may be purely mathematical or may have real life settings. Both types of items involve transfer of knowledge and skills to new situations and interactions among reasoning skills are usually a feature. Problems requiring reasoning may do so in different ways, because of the novelty of the context or the complexity of the situation or because any solution to the problem must involve several steps, perhaps drawing on knowledge and understanding from different areas of mathematics.

Even though of the many behaviours listed within the reasoning domain are those that may be drawn on in thinking about and solving novel or complex problems, each by itself represents a valuable outcome of mathematics education, with the potential to influence learners' thinking more generally. For example, reasoning involves the ability to observe and make conjectures. It also involves making logical deductions based on specific assumptions and rules, and justifying results.

This cognitive domain covers the following behaviours:

1. **Analyze**	Determine and describe or use relationships between variables or objects in mathematical situations; use proportional reasoning (fourth grade); decompose geometric figures to simplify solving a problem; draw the net of a given unfamiliar solid; visualize transformations of three-dimensional figures; compare and match different representations of the same data (fourth grade); and make valid inferences from given information.
2. **Generalize**	Extend the domain to which the result of mathematical thinking and problem solving is applicable by restating results in more general and more widely applicable terms.
3. **Synthesize/Integrate**	Combine (various) mathematical procedures to establish results, and combine results to produce a further result. Make connections between different elements of knowledge and related representations, and make linkages between related mathematical ideas.
4. **Justify**	Provide a justification for the truth or falsity of a statement by reference to mathematical results or properties.
5. **Solve Non-routine Problems**	Solve problems set in mathematical or real life contexts where target students are unlikely to have encountered closely similar items, and apply mathematical procedures in unfamiliar or complex contexts. Use geometric properties to solve non-routine problems.

Australian students performed relatively better, overall, in this cognitive domain than in the other two. This differs from those countries which were high-performing in terms of overall mathematics score, which generally had relatively poorer results in this domain compared with their performance in the other two cognitive domains. About one-quarter of the score points are based on items in the *reasoning* cognitive domain.

Table 2.9 shows that students in Year 4 in Australia performed at a level higher than the international average, although still at a significantly lower level than any of the high-performing countries, and lower than similar countries such as England and the United States. Australian students' performance was not significantly different from that of students in New Zealand, Italy or Scotland. Singapore had the highest achievement level, and outperformed all countries other than Hong Kong and Chinese Taipei. However the gap between the average for Australia and the average score for Singapore was 67 scale points – two-thirds of a standard deviation.

Students in Year 4 in the Australian Capital Territory, New South Wales and Victoria achieved at a level significantly higher than the international mean, while students in other states achieved at a level no different from the international mean.

Table 2.9 Average mathematics achievement overall and by gender for *Reasoning* cognitive domain, Year 4

Countries / States		Average scale score (se)	Girls average scale score		Boys average scale score		Difference (Absolute value)
Singapore	▲	574 (6.1)	578 (6.2)		570 (6.8)		8 (4.7)
Hong Kong, SAR	▲	564 (3.7)	565 (4.0)		563 (3.8)		2 (2.7)
Chinese Taipei	▲	563 (2.2)	565 (2.6)		562 (2.7)		3 (2.9)
Japan	▲	562 (1.7)	559 (2.1)		564 (2.6)		6 (3.2)
Belgium (Flemish)	▲	541 (2.2)	541 (2.6)		541 (2.8)		0 (3.1)
England	▲	537 (3.5)	539 (4.0)		536 (4.2)		3 (4.2)
Netherlands	▲	535 (2.9)	533 (3.4)		536 (3.2)		4 (3.2)
Latvia	▲	531 (3.2)	531 (3.3)		531 (4.1)		0 (3.9)
Australian Capital Territory	▲	530 (13.0)	514 (13.0)		545 (17.7)		31 (19.8)
Russian Federation	▲	526 (4.8)	524 (5.2)		528 (4.9)		4 (3.4)
Lithuania	▲	526 (3.1)	527 (3.7)		529 (3.9)		2 (3.6)
Hungary	▲	524 (3.2)	525 (4.0)		524 (3.8)		1 (4.4)
United States	▲	519 (2.5)	517 (2.6)		522 (2.9)		5 (2.5)
New South Wales	▲	518 (8.6)	523 (7.6)		514 (10.5)		10 (7.1)
Cyprus	▲	516 (2.4)	515 (2.7)		517 (3.0)		2 (3.1)
Victoria	▲	514 (6.4)	513 (8.0)		514 (6.3)		1 (6.4)
Tasmania		508 (11.6)	512 (12.6)		500 (10.5)		11 (8.0)
AUSTRALIA	▲	507 (3.6)	507 (3.9)		507 (4.2)		0 (3.4)
New Zealand	▲	503 (2.2)	502 (2.9)		504 (2.4)		2 (3.1)
Italy		499 (4.0)	496 (4.7)		502 (4.1)		6 (3.7)
Scotland		498 (3.1)	495 (3.5)		502 (4.0)		7 (4.3)
South Australia		497 (7.2)	494 (7.7)		499 (8.1)		5 (6.6)
International Avg.		495 (0.7)	496 (0.9)		495 (0.8)		1 (0.9)
Moldova, Rep. of		**494 (4.9)**	**501 (5.5)**	↑	**488 (5.6)**		**13 (5.2)**
Queensland		493 (6.4)	490 (8.7)		498 (6.1)		8 (7.7)
Northern Territory		492 (11.4)	489 (15.7)		495 (11.8)		6 (16.3)
Slovenia	▼	485 (2.6)	486 (3.0)		485 (3.6)		1 (4.2)
Western Australia		**483 (7.5)**	**478 (7.8)**		**490 (7.7)**	⇧	**12 (5.2)**
Norway	▼	468 (2.1)	466 (2.5)		470 (2.8)		4 (3.3)
Armenia	▼	**445 (3.1)**	**449 (3.4)**	↑	**442 (3.4)**		**7 (2.9)**
Iran, Islamic Rep. of	▼	400 (3.4)	406 (6.0)		396 (4.3)		10 (7.7)
Morocco	▼	368 (4.4)	366 (5.6)		370 (4.7)		4 (5.4)
Philippines	▼	**359 (7.4)**	**366 (8.8)**	↑	**352 (6.6)**		**13 (5.7)**
Tunisia	▼	340 (4.2)	340 (5.8)		339 (4.7)		1 (6.3)

▲ Country's score significantly higher than the International average
▼ Country's score significantly lower than the International average
↑ Female score significantly higher than male score
⇧ Male score significantly higher than female score

The older (Year 8) cohort of Australian students, as shown in Table 2.10, also performed relatively better in this domain than in other domains. The average of 515 was substantially and significantly higher than the international average, although there is a large jump in score from this to that of the next highest in the table: Estonia with an average score of 523.

Table 2.10 Average mathematics achievement overall and by gender for *Reasoning* cognitive domain, Year 8

Countries / States		Average scale score (se)	Girls average scale score		Boys average scale score		Difference (Absolute value)
Singapore	▲	**583 (3.5)**	**589 (3.3)**	↑	**579 (4.4)**		**10 (3.5)**
Korea, Rep. of	▲	582 (1.7)	580 (2.4)		584 (2.1)		5 (2.8)
Chinese Taipei	▲	**576 (4.2)**	**581 (4.3)**	↑	**572 (4.8)**		**9 (3.8)**
Japan	▲	576 (1.8)	575 (3.7)		576 (3.0)		1 (5.6)
Hong Kong, SAR	▲	569 (3.1)	571 (3.5)		567 (4.4)		3 (5.0)
Netherlands	▲	541 (3.8)	540 (4.3)		542 (4.5)		1 (4.2)
New South Wales	▲	535 (9.8)	526 (13.4)		547 (11.5)		21 (16.5)
Belgium (Flemish)	▲	533 (2.8)	531 (3.8)		536 (3.6)		5 (4.8)
Hungary	▲	529 (3.1)	530 (3.7)		528 (3.5)		2 (3.6)
Estonia	▲	**523 (3.0)**	**526 (3.4)**	↑	**519 (3.4)**		**7 (3.2)**
AUSTRALIA	▲	515 (4.0)	515 (5.1)		516 (5.1)		1 (6.2)
Australian Capital Territory	▲	**514 (10.4)**	**527 (11.0)**	↑	**499 (10.9)**		**28 (8.0)**
Scotland	▲	**513 (3.4)**	**517 (4.3)**	↑	**509 (3.4)**		**8 (3.7)**
South Australia	▲	512 (10.5)	510 (9.3)		516 (15.1)		6 (15.1)
New Zealand	▲	**509 (5.2)**	**519 (5.4)**	↑	**499 (6.7)**		**19 (6.2)**
England	▲	509 (4.7)	513 (4.8)		506 (5.9)		8 (5.4)
Sweden	▲	508 (3.3)	511 (4.1)		505 (3.3)		5 (3.6)
Victoria	▲	507 (6.7)	513 (6.7)		502 (9.5)		11 (9.5)
United States	▲	505 (3.3)	505 (3.3)		506 (3.7)		0 (2.4)
Western Australia	▲	505 (6.1)	507 (6.5)		504 (7.1)		3 (6.6)
Slovak Republic	▲	504 (3.2)	505 (3.3)		503 (4.2)		2 (4.2)
Queensland	▲	504 (5.7)	510 (5.8)		499 (8.1)		11 (8.1)
Malaysia	▲	503 (3.4)	505 (3.9)		501 (3.9)		4 (3.9)
Latvia	▲	500 (3.4)	504 (3.6)		496 (4.4)		8 (4.2)
Russian Federation	▲	496 (3.6)	498 (4.0)		494 (3.8)		3 (3.1)
Tasmania	▲	**495 (11.9)**	**512 (13.3)**	↑	**481 (12.0)**		**31 (11.1)**
Slovenia	▲	**494 (2.5)**	**500 (3.1)**	↑	**488 (3.2)**		**12 (3.9)**
Italy	▲	489 (2.9)	486 (3.0)		491 (3.4)		5 (2.7)
Lithuania	▲	**489 (2.6)**	**492 (3.0)**	↑	**484 (3.3)**		**8 (2.9)**
Israel	▲	483 (3.3)	483 (3.4)		483 (4.6)		0 (4.6)
Norway	▲	**479 (2.8)**	**486 (3.1)**	↑	**472 (3.5)**		**14 (3.3)**
Bulgaria		471 (3.9)	471 (5.2)		471 (4.4)		1 (5.7)
Armenia		468 (2.8)	473 (3.4)		463 (4.3)		9 (5.3)
Serbia		**468 (2.6)**	**472 (3.3)**	↑	**464 (2.8)**		**7 (3.2)**
INTERNATIONAL AVG.		**467 (0.5)**	**469 (0.5)**	↑	**465 (0.6)**		**4 (0.6)**
Northern Territory		462 (10.2)	464 (10.6)		460 (10.9)		5 (8.7)
Romania	▼	458 (4.5)	460 (5.0)		456 (5.0)		4 (4.6)
Cyprus	▼	**455 (1.7)**	**465 (2.3)**	↑	**446 (2.4)**		**20 (3.3)**
Moldova, Rep. of	▼	**453 (4.0)**	**458 (4.2)**	↑	**448 (4.6)**		**10 (3.7)**
Macedonia, Rep. of	▼	**438 (3.7)**	**444 (4.1)**	↑	**432 (4.7)**		**13 (4.7)**
Jordan	▼	**433 (3.7)**	**442 (4.1)**	↑	**425 (5.3)**		**18 (6.2)**
Bahrain	▼	**424 (2.2)**	**435 (2.5)**	↑	**412 (3.2)**		**23 (3.8)**
Iran, Islamic Rep. of	▼	417 (2.8)	423 (3.8)		413 (4.4)		10 (6.2)
Lebanon	▼	410 (3.0)	407 (3.5)		413 (4.9)		6 (5.9)
Chile	▼	409 (3.5)	406 (4.1)		412 (4.2)		6 (4.5)
Indonesia	▼	406 (4.3)	405 (4.4)		406 (4.8)		1 (3.0)
Palestinian Nat'l Auth.	▼	**404 (2.7)**	**410 (3.8)**	↑	**397 (4.2)**		**14 (6.0)**
Egypt	▼	400 (3.6)	402 (4.5)		399 (5.1)		3 (6.5)
Tunisia	▼	**399 (2.7)**	**390 (3.3)**		**410 (3.3)**	⇧	**20 (3.8)**
Morocco	▼	**391 (3.2)**	**387 (3.9)**		**397 (4.0)**	⇧	**11 (4.4)**
Philippines	▼	**358 (5.8)**	**363 (5.9)**	↑	**350 (6.4)**		**13 (4.1)**
Botswana	▼	353 (3.7)	356 (3.5)		351 (4.5)		6 (3.0)
Saudi Arabia	▼	348 (4.3)	347 (5.7)		349 (6.1)		2 (8.4)
Ghana	▼	313 (4.0)	309 (4.6)		317 (5.0)		8 (5.2)
South Africa	▼	287 (5.0)	287 (5.6)		286 (5.7)		1 (5.1)

▲ Country's score significantly higher than the International average
▼ Country's score significantly lower than the International average
↑ Female score significantly higher than male score
⇧ Male score significantly higher than female score

The average for students in Australia was significantly lower than that of students in the top five scoring Asian countries: Singapore, Republic of Korea, Chinese Taipei, Japan and Hong Kong, and also lower than that of the Netherlands, Belgium (Flemish), Hungary and Estonia, but not significantly different from the performance of students in Scotland, New Zealand, England, Sweden and the United States. As at the Year 4 level, this domain was the weakest of the three for the top scoring countries, but the strongest for Australia, although noting that Australia was still significantly outperformed by these countries in this domain. The difference between the Australian average and the average for Singapore was 68 scale points, again two-thirds of a standard deviation.

At Year 8 level, students in all states apart from the Northern Territory performed at a level significantly higher than the international average, with students in the Northern Territory performing at a level not significantly different from the international average (Figure 2.10).

There were very few gender differences in this domain at Year 4 level. In the Republic of Moldova, Armenia and the Philippines, females significantly outperformed males. Internationally, there were no gender differences in favour of males; however, in Western Australia males scored significantly higher than females.

At Year 8 there were gender differences internationally, and in 16 individual countries, and in Tasmania and ACT in favour of females. Only in Tunisia and Morocco were females significantly outperformed by males in the *reasoning* cognitive domain.

State differences

Table 2.11 synthesises the multiple comparisons for Year 4 carried out to examine differences between states. Students in New South Wales, Victoria and the Australian Capital Territory outperformed students in Queensland and Western Australia, and those in the ACT also outperformed students in South Australia and the Northern Territory.

The difference in mean scores between the highest (ACT) and lowest (WA) achieving states was 47 scale points – around half a standard deviation.

Table 2.11 Multiple comparisons of states' mathematics achievement for *Reasoning* cognitive domain, Year 4

State	Mean	SE	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	518	8.6		▲	●	▲	●	●	●
VIC	514	6.4		▲	●	▲	●	●	●
QLD	493	6.4	▼		●	●	●	●	▼
SA	497	7.2	●	●		●	●	●	●
WA	483	7.5	▼	●	●		●	●	●
TAS	508	11.6	●	●	●	●		●	●
NT	492	11.4	●	●	●	●	●		●
ACT	530	13.0	●	▲	▲	▲	●	▲	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state

As shown in Table 2.12, Students in Year 8 in New South Wales performed strongly in this cognitive domain, significantly outscoring students in all states other than South Australia and the Australian Capital Territory. The difference between the average for students in New South Wales and students in the Northern Territory was 74 scale points, or three-quarters of a standard deviation.

Table 2.12 Multiple comparisons of states' mathematics achievement for *Reasoning* cognitive domain, Year 8

State	Mean	SE	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	535	9.8	▲	▲	●	▲	▲	▲	●
VIC	507	6.7		●	●	●	●	▲	●
QLD	504	5.7	●		●	●	●	▲	●
SA	512	10.5	●	●		●	●	▲	●
WA	505	6.1	●	●	●		●	▲	●
TAS	495	11.9	●	●	●	●		▲	●
NT	461	10.2	▼	▼	▼	▼	▼		▼
ACT	514	10.4	●	●	●	●	●	▲	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state

Overview of differences

This chapter has investigated differences in achievement, both internationally and within Australia, in the cognitive domains tested in TIMSS 2002. These domains, *knowing*, *applying* and *reasoning*, are critical to complete mathematics understanding and are tested along with the content domains.

At Year 4 level, the achievement of Australian students in the overall mathematics score was not significantly different from the international average. Students in Singapore achieved the highest scores internationally in the overall mathematics content score, and in all three cognitive domains, while Australian students scored at a level not significantly different from the international average in *knowing* and *applying*, but significantly higher than the international average in *reasoning*. Within Australia, the Australian Capital Territory was the highest scoring state in the overall mathematics content score and also scored the highest in each of the cognitive domains.

Some states achieved a score higher than the international average in some domains, but none in all three. Students in the ACT scored higher than the international average in the *knowing* cognitive domain. The ACT, NSW and Victoria scored higher than the international average in the *reasoning* cognitive domain. No state scored at a higher level than the international average in the *applying* cognitive domain.

At Year 8 level, Australian students performed above the international average in the overall mathematics score as well as in all three cognitive domains. Students in Singapore achieved the highest overall mathematics score and the highest average scores in the *applying* and *reasoning* cognitive domains. Within Australia, NSW was the highest scoring state in mathematics overall, and in all three cognitive domains. Students in NSW, Victoria, Queensland, South Australia and the ACT performed above the international averages in all three cognitive domains. Western Australia achieved above the international averages in *applying* and *reasoning* and students in Tasmania achieved above the international average in *reasoning*.

There were gender differences apparent in each domain to different degrees. At Year 4, there were very few differences, with a slight tendency for males to do better than females in *applying*. At Year 4 there were also few gender differences in *knowing* and *reasoning*. However at Year 8 females significantly outscored males in almost one-third of all countries, whilst the reverse was true in only a few countries.

3. Profiles of Relative Performance on the Cognitive Domains within Australia

This chapter explores relative strengths and weaknesses in Australia and across states. Regardless of international ranking, the profiles of achievement showed that many countries performed relatively better or worse in one or more cognitive domains than they did in the others. Each of the following figures displays the difference between average performance in each cognitive area and Australia or the state's average performance overall. The average of the cognitive domain for the country (or state) is set to zero, so that above average or below average performance can be highlighted for each of the three domains. Relatively better achievement in a cognitive domain is shown when the 95% confidence interval is completely above the zero line and relatively poorer performance when the confidence interval is completely below the zero line.

For example at Year 4 level Singapore was the highest achieving country, and scored almost 100 scale points higher than Australia. However the performance of Singaporean students was not even across the cognitive domains. The strength of Singaporean students was in the cognitive domain *knowing*, and their relative weakness in the cognitive domain *reasoning*.

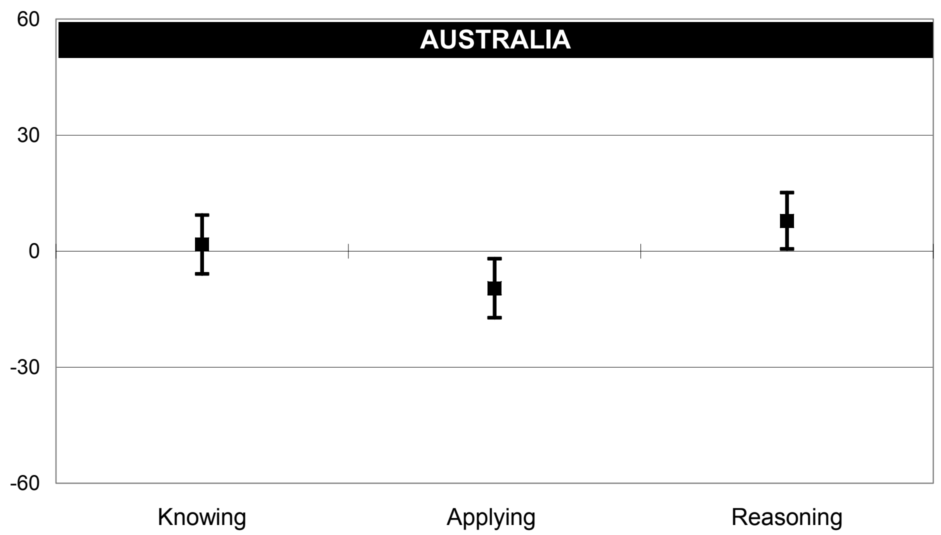


Figure 3.1 Differences from Australian average of mathematics cognitive domain scale scores, Year 4

Australia's relative strengths and weakness in the cognitive domains at Year 4 level are shown in Figure 3.1, and although the differences are not large, the strength is in the cognitive domain of *reasoning* and the weakness in the cognitive domain of *applying*.

Similar patterns can be seen in the state breakdowns of these data (Figure 3.2). Although the differences are not large, there is a trend for achievement in *reasoning* to be comparatively higher than in the other domains, and for achievement in *applying* to be comparatively lower than in the other domains.

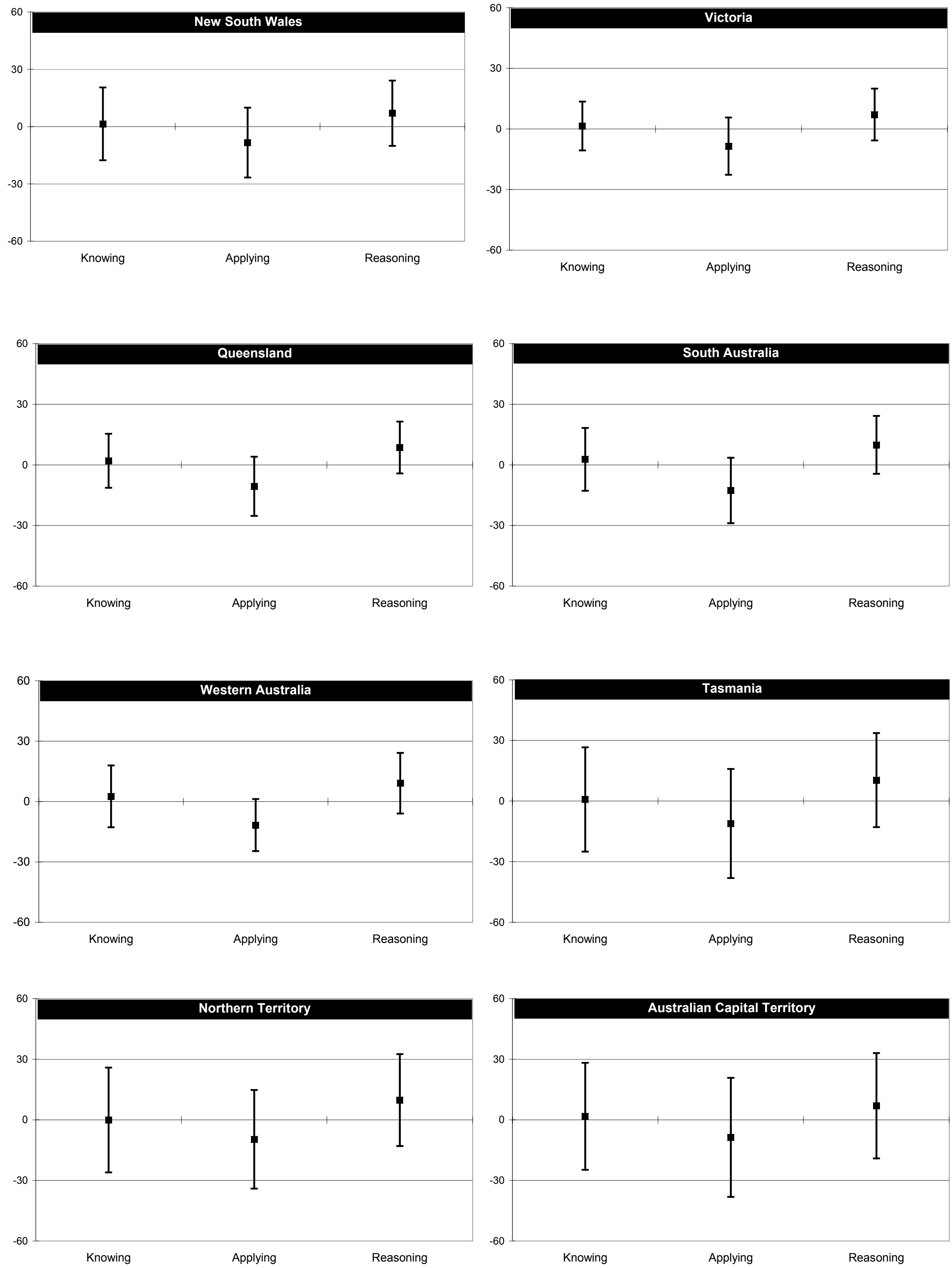


Figure 3.2 Differences from state's own average of mathematics cognitive domain scale scores, Year 4

At Year 8 level the picture is somewhat different. At this level, the weakness at the national level is in the domain of *knowing*; however the strength is still in the area of *reasoning*. Singapore, the highest achieving country at Year 8 as well as at Year 4, again had a very different pattern, with comparative weakness in the cognitive domain of *knowing* and *reasoning* and strength in the area of *applying*.

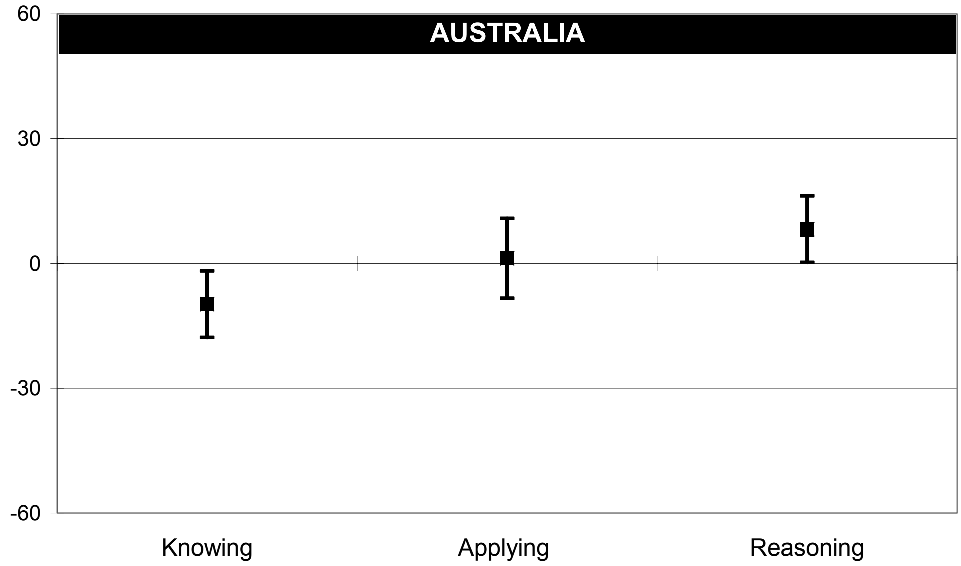


Figure 3.3 Differences from Australian average of mathematics cognitive domain scale scores, Year 8

The patterns for each of the states look similar, however because of the large error bars; it is not possible to say that there are significant differences other than in two instances. For Queensland, performance in the cognitive domain of *knowing* is significantly lower than the Queensland average performance overall, and in Western Australia, performance in the *reasoning* domain is significantly higher than the Western Australian average.

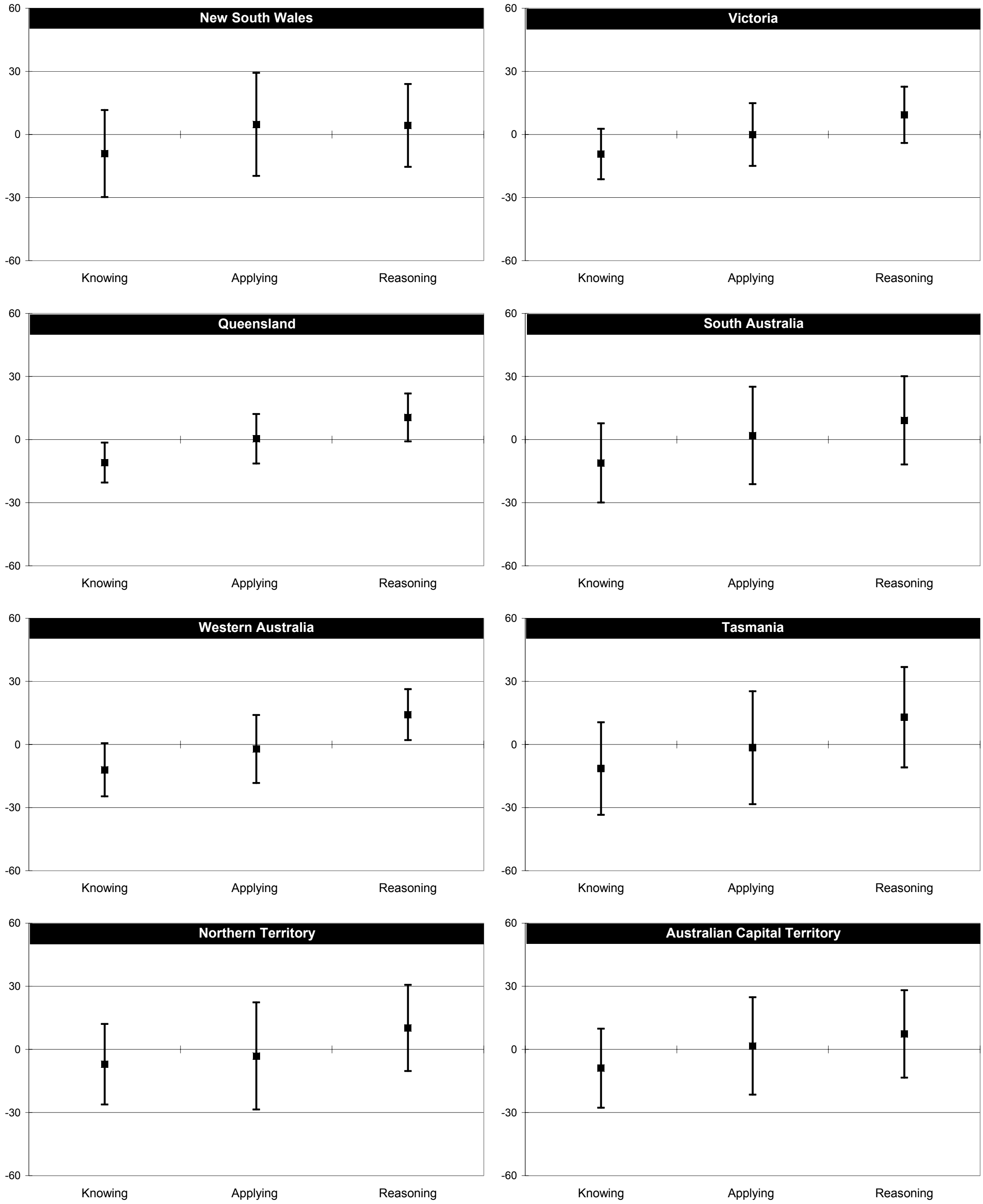


Figure 3.4 Differences from state's own average of mathematics cognitive domain scale scores, Year 8

If there are differences in relative performance between states, these differences may be related to factors such as different emphases in intended curriculum, or differences in the implemented curriculum. This report forms the basis on which to monitor changes in achievement in the cognitive domains measured in TIMSS, which may reflect changes in curriculum in each state.

Relative achievement in content and cognitive domains

The TIMSS data provides a profile of achievement in both content and cognitive domains. This report has explored Australian students' performance in the cognitive domains, and this section provides a summary of Australian students' performance in the content domains as described in the TIMSS National Report (Thomson & Fleming, 2004a). Figure 3.5 shows relative achievement in the mathematics content areas for Year 4 students, and Figure 3.6 relative achievement for Year 8 students.

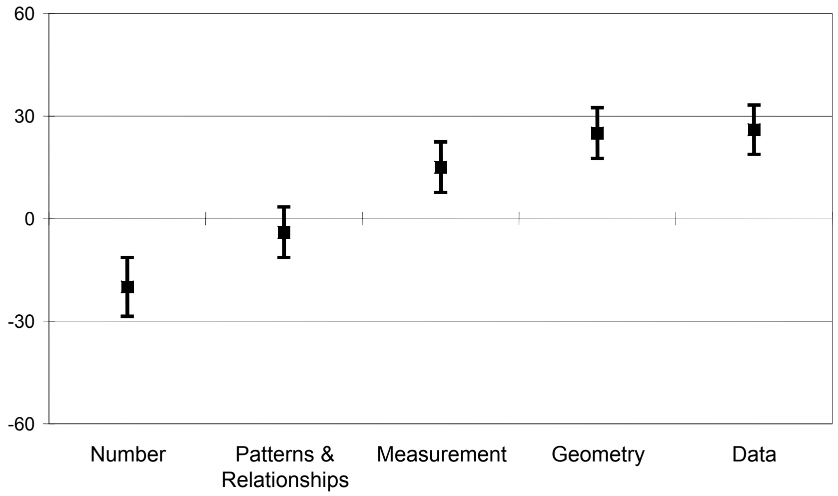


Figure 3.5 Australian Year 4 students' performance in TIMSS mathematics content areas

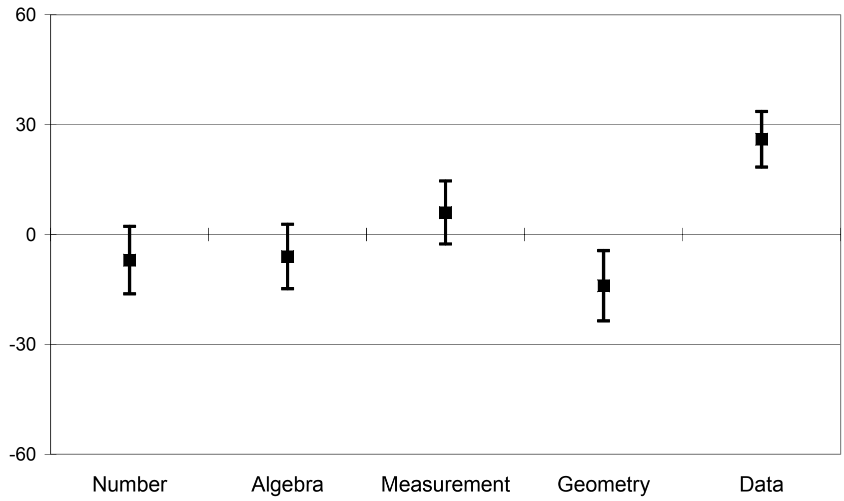


Figure 3.6 Australian Year 8 students' performance in TIMSS mathematics content areas

To summarise, Year 4 students' relative strengths were in the content domains of *measurement*, *geometry* and *data* and their relative weakness was in the content domain of *number*. In the cognitive domains, students' relative strength was in the *reasoning* cognitive domain and they were relatively weak in the *applying* cognitive domain.

Australian Year 8 students' relative strength was in the *data* content domain, and their relative weakness was in the *geometry* content domain. In the cognitive domains, Year 8 students' relative strength was in *reasoning* and their relative weakness was in the area of *knowing.*

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Appendix A: Multiple comparison tables for overall mathematics achievement by state

Table A.1 Year 4 overall mathematics achievement by state

STATE	Mean	se	ACT	NSW	VIC	TAS	SA	QLD	NT	WA
Australian Capital Territory	523	14		●	●	●	●	●	●	▲
New South Wales	510	9	●		●	●	●	●	●	▲
Victoria	508	7	●	●		●	●	●	●	▲
Tasmania	497	13	●	●	●		●	●	●	●
South Australia	485	8	●	●	●	●		●	●	●
Queensland	484	7	●	●	●	●	●		●	●
Northern Territory	479	15	●	●	●	●	●	●		●
Western Australia	472	8	▼	▼	▼	●	●	●	●	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state

Table A.2 Year 8 overall mathematics achievement by state

STATE	Mean	se	NSW	ACT	SA	VIC	QLD	WA	TAS	NT
New South Wales	530	12		●	▲	●	▲	●	●	▲
Australian Capital Territory	507	10	●		●	●	●	●	●	▲
South Australia	501	11	▼	●		●	●	●	●	●
Victoria	495	6	●	●	●		●	●	●	●
Queensland	490	6	▼	●	●	●		●	●	●
Western Australia	487	8	●	●	●	●	●		●	●
Tasmania	476	12	●	●	●	●	●	●		●
Northern Territory	449	14	▼	⬇	●	●	●	●	●	

▲ score significantly higher than that for comparison state
▼ score significantly lower than that for comparison state
● score not significantly different from that of the comparison state