Science test analysis

Report to the Queensland Education Performance Review Implementation Steering Committee

May 2011

Queensland Government

Queensland Studies Authority

www.qsa.qld.edu.au
Queensland Studies Authority

Contents

1. Executive summary

In 2009, Professor Geoff Masters released a report, *A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools*. The review followed the release of results from the 2008 National Assessment Program – Literacy and Numeracy (NAPLAN) test and the 2007 Trends in International Mathematics and Science Study (TIMSS).

The Government's response to Professor Masters' report included the following action.

> The Queensland Studies Authority (QSA) will:
>
> Analyse Queensland students' performance in national and international tests to identify priority areas for professional development programs.

This report contains the interim results of the analysis of Queensland student performance in three relevant tests:

- National Assessment Program (NAP) — Science Literacy 2006 (sat by Year 6 students),
- Program for International Student Assessment (PISA) 2006 (sat by 15-year-old students in Years 10 and 11) and the
- Trends in International Mathematics and Science Study (TIMSS) 2007 (sat by Years 4 and 8 students)

with consideration of priorities for teacher professional development in science.

The results in these testing programs showed very little relative difference in the performance of Queensland students in different areas of science literacy. It is of greater interest to note that the results for Queensland students are relatively poor at younger year levels, but show great improvement and are comparable to other large jurisdictions by secondary school.

This suggests that professional development is best targeted, not in certain domains, but rather at particular year levels. International research suggests that the weaknesses of teaching science at the lower primary year levels can be attributed to weaker content knowledge of teachers at these year levels. This leads to less confidence in teaching the subject effectively in interesting and engaging ways, and it is in the areas of *Applying* and *Reasoning* (as opposed to *Knowing*) that Queensland students show relative weakness in the lower primary school. Aligning professional development in these areas with the implementation of the Australian Curriculum will provide a meaningful context in which teachers could re-examine their content knowledge and build their pedagogical content knowledge.

Based on the analysis of Queensland students' performance in national and international tests, this report makes five recommendations:

1. That professional development be targeted at teachers of P – Year 6.
2. That professional development focus on developing content knowledge and pedagogical content knowledge.
3. That professional development for teachers of science be aligned with the implementation of the Australian Curriculum.
4. That the findings of this report inform current and planned school sector support and school leadership.
5. That providers of pre-service primary teacher education prepare teachers better by placing a greater focus on science content and pedagogical content knowledge.

2. Introduction

The Government's response to Professor Geoff Masters' (2009) report *A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools* (the Masters Report) included the following action in relation to Masters' Recommendation 4.

> The Queensland Studies Authority (QSA) will:
>
> Analyse Queensland students' performance in national and international tests to identify priority areas for professional development programs.

The decision to establish the review undertaken by Masters followed the release of results from the 2008 National Assessment Program — Literacy and Numeracy (NAPLAN) test results and the 2007 Trends in International Mathematics and Science Study (TIMSS) results.

The key milestones in the Queensland Education Performance Review: Implementation Steering Committee (QEPRISC) work plan clarify that the student performance data to be analysed are those from the:

- National Assessment Program (NAP) — Science Literacy
- Program for International Student Assessment (PISA)
- Trends in International Mathematics and Science Study (TIMSS).

This report contains an analysis of student performance data for those three tests, and considers priorities for professional development programs for teaching science. As the following table represents, these data offer quite strong coverage of science performance across the years of schooling.

Science testing program	Year level tested
TIMSS 2007	Year 4
NAP — Science Literacy 2006	Year 6
TIMSS 2007	Year 8
PISA 2006	Years 10 & 11 (15-year-olds)

3. Methodology

The Masters Report Chapter 2, *National Comparisons*, presented tables ranking Australian states and territories based on the mean scores in the 2008 NAPLAN, 2007 TIMSS and 2007 PISA tests.

While Masters noted that many of the differences in mean scores were not statistically significant, these tables represent Queensland students as underperforming, compared with students in other jurisdictions.

Fensham and Maxwell note the following in their analysis of Queensland PISA data:

> Ranking the mean scores of any group of students — for a country, state or any other grouping — can be misleading because there are several sources of error … In the official OECD International Report and the ACER Australian Report for PISA, a statistic called the standard error (SE) is used to express the uncertainty associated with the sampling and measurement errors. It is used to construct a confidence interval. Groups whose confidence intervals overlap are described as not significantly different (2008; p. 17).

Depending on how comparisons are made, however, it is possible to compare groups where the confidence intervals overlap, particularly when comparing rank orders of jurisdictions on the same testing occasion. A discussion of the interpretations of confidence intervals is given in Appendix 3 of this report. In this report, the mean scores are represented with 95% confidence intervals, but some conclusions can be drawn even where confidence intervals overlap to some extent.

The results in TIMSS and PISA are reported as scores for the total tests and scores in the domains tested. In order to identify priority areas for professional development programs, the Australian jurisdictional means with reported confidence intervals were analysed by domains for these tests.

Unlike PISA and TIMSS, NAP — Science Literacy results are reported by total scores only and not separately by domain. Therefore, results on the released items were analysed to determine the domains which professional development should target.

4. Analysis

4.1 NAP — Science Literacy 2006

The NAP — Science Literacy test is sat by a sample of Year 6 students every three years. The first of these was in 2003.

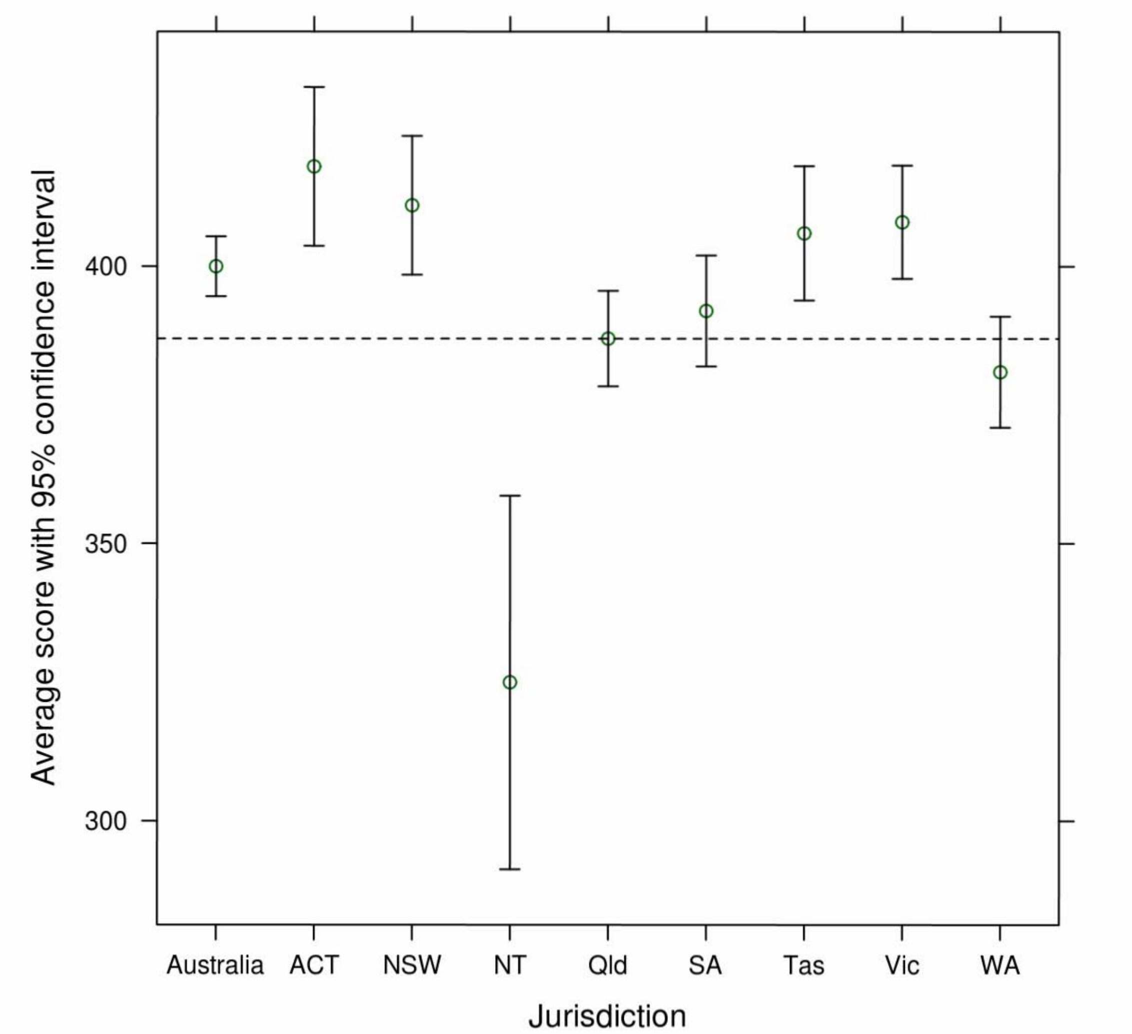
The following table summarises the seven domains of science literacy that the contractors who constructed the NAP — Science Literacy 2006 test were commissioned to test and report on.

Table 1: Domains assessed by NAP — Science Literacy 2006

Major scientific concepts	Scientific literacy strands
Life and Living Living together Structure and function Biodiversity, change and continuity	**Strand C** Using scientific understandings for describing and explaining natural phenomena, and interpreting reports about phenomena
Natural and Processed Materials Materials and their uses Structure and properties Reactions and change	**Strand B** Interpreting evidence and drawing conclusions from their own or other's data, critiquing the trustworthiness of evidence and claims made by others, and communicating findings
Energy and Change Energy and us Transferring energy Energy sources and receivers	**Strand A** Formulating or identifying investigable questions and hypotheses, planning investigations and collecting
Earth and Beyond Earth, sky and people The changing earth Our place in space	

The following figure compares results from all Australian jurisdictions.

Figure 1: Australian jurisdictional means with confidence intervals for the National Assessment Program Science Literacy 2006

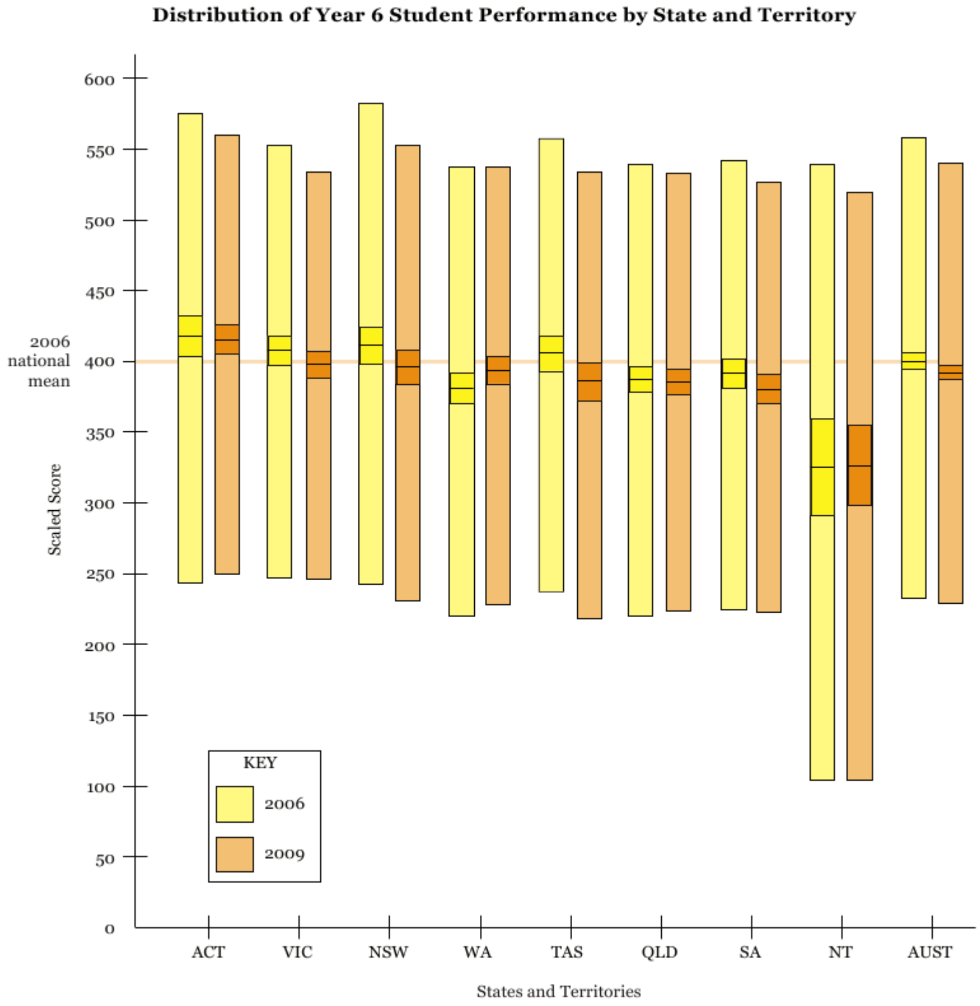


The Queensland mean score with confidence intervals shows considerable overlap with those for South Australia and Western Australia and is clearly better than students in the Northern Territory. It is below the mean scores for Tasmania, the Australian Capital Territory, New South Wales and Victoria.

The intention of the analysis exercise in relation to NAP — Science Literacy was to obtain Queensland and Australian data for all the test items, in order to determine the areas in which Queensland students did not perform as well as students in other jurisdictions. Professional development could then target these areas.

The Benchmarking and Educational Measurement Unit (BEMU), which is now a part of the Australian Curriculum, Assessment and Reporting Authority (ACARA), provided the QSA with the data file for all items for the whole of Australia and Queensland for the NAP — Science Literacy 2006. However, BEMU were unable to release all items, as many of them will be re-used in future tests. For this analysis, the QSA had access only to those 46 items that had been released as part of the *School Release Materials*, and as Queensland students performed relatively poorly on only four of these, this information was not of great diagnostic value. This highlights limitations in using results from this testing to inform teaching practice. A description of the four items on which relatively poor performance by Queensland students was evident is given in Appendix 1.

In 2010, the results for the 2009 test were released. A comparison of the 2006 and 2009 data is shown below. (ACARA 2010; p. xiv)*



Note: 2009 results scaled to 2006.

These results show that the Queensland mean changed very little from 2006 to 2009. There were significantly lower means in 2009 than in 2006 for Victoria, New South Wales, Tasmania and South Australia. This also led to a lower national mean.

* Australian Curriculum, Assessment and Reporting Authority 2010 *2009 National Assessment Program — Science Literacy Report.* ACARA. Accessed 6 April 2011, www.mceecdya.edu.au/verve/_resources/NAP-L_2009_PublicReport_HighRes.pdf

4.2 PISA 2006

PISA is sat by a sample of 15-year-old students across a number of OECD counties. In Queensland, the students are in Years 10 and 11. The following table summarises the nine domains of Scientific Literacy tested by PISA 2006

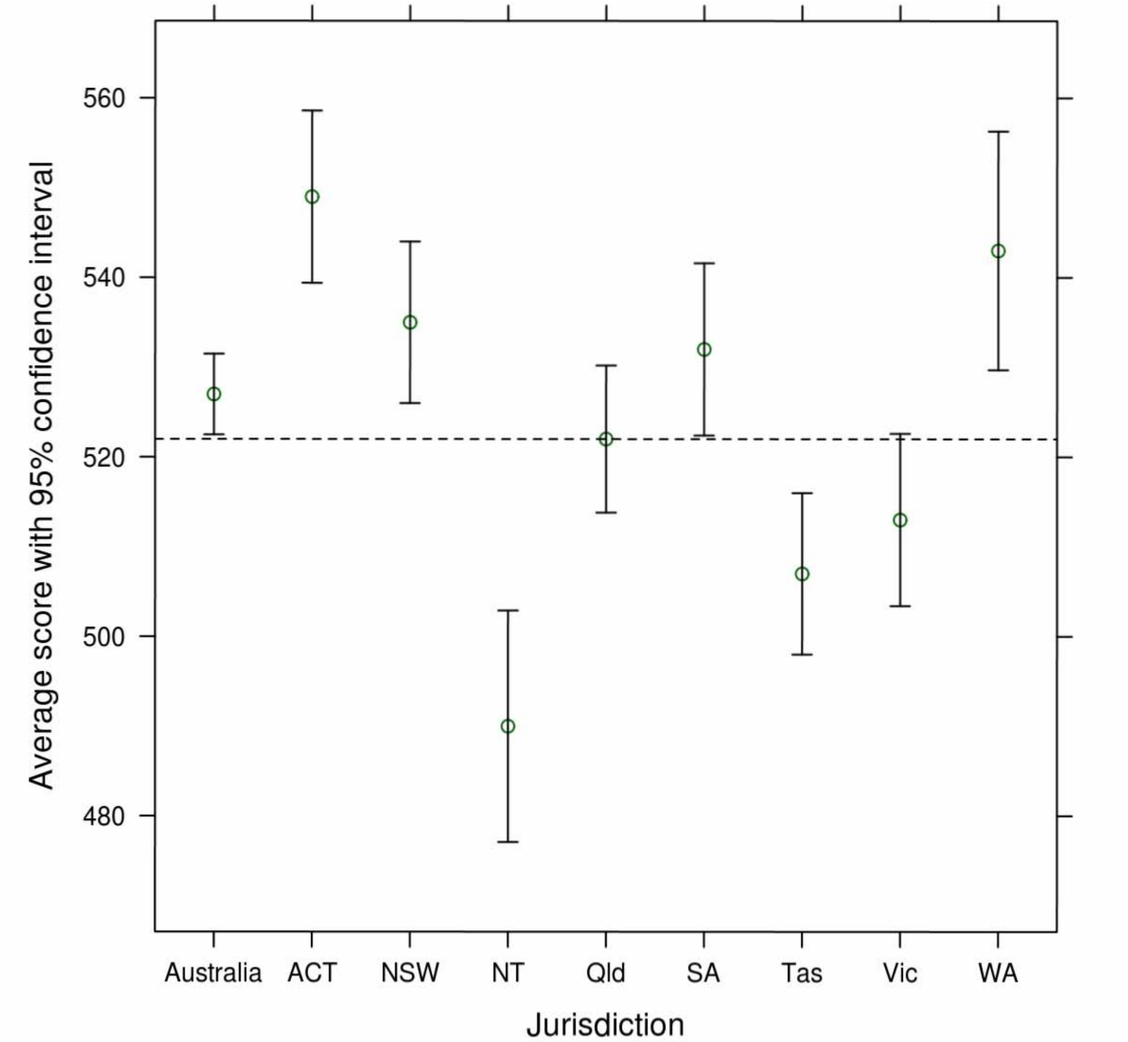
Table 2: Domains assessed by PISA 2006

Knowledge of science content areas	Knowledge about science categories	Competencies
Living systems Cells Humans Populations Ecosystems Biosphere	**Scientific enquiry** Origin Purpose Experiments Data Measurements Characteristics of results	**Identifying scientific issues** Recognising issues that are possible to investigate scientifically Identifying keywords to search for scientific information Recognising the key features of a scientific investigation
Physical systems Structure of matter Properties of matter Chemical changes of matter Motions and forces Energy and its transformation Interactions of energy and matter	**Scientific explanations** Types Formation Rules Outcomes	**Explaining phenomena scientifically** Applying knowledge of science in a given situation Describing or interpreting phenomena scientifically and predicting changes Identifying appropriate descriptions, explanations, and predictions
Earth and space systems Structures of earth systems Energy in earth systems Change in earth systems Earth's history Earth in space		**Using scientific evidence** Interpreting scientific evidence, and making and communicating conclusions Identifying the assumptions, evidence and reasoning behind conclusions Reflecting on the societal implications of science and technological developments
Technology systems Role of science-based technology Relationships between science and technology Concepts Important principles		

Australian data are available for eight of the nine areas listed in Table 2. The content area *Technology systems* is not analysed at an Australian level because it contains too few items for analysis. The data for *Knowledge of science content areas* and *Knowledge about science categories* are not able to be scaled by jurisdiction.

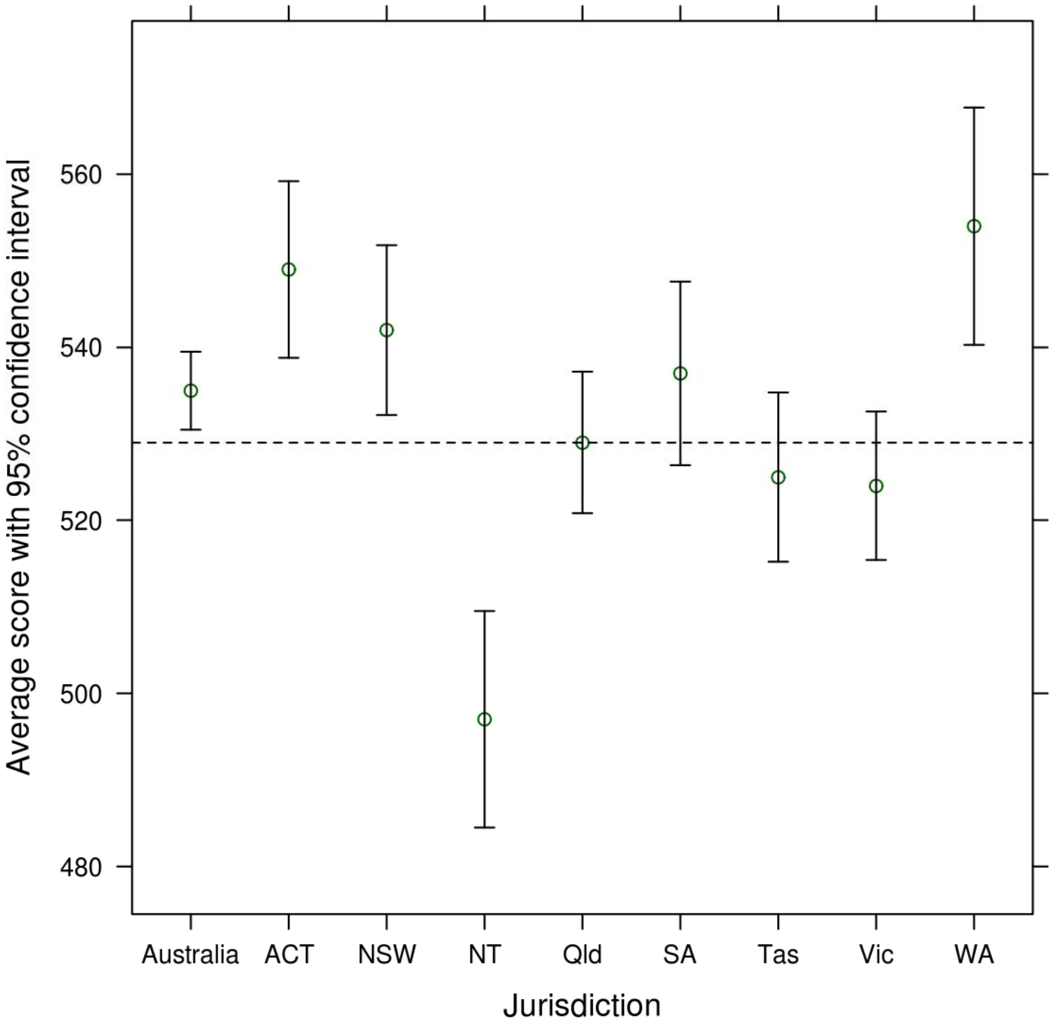
Data at a jurisdictional level are available for only the three competencies: *Identifying Scientific Issues*, *Explaining Phenomena Scientifically* and *Using Scientific Evidence*. These data are presented in the following figures (Thomson & De Bortoli, 2008). It is interesting to note that Queensland's place in the rank order of jurisdictions for each competency is similar to that which is evident in the whole test. This trend is repeated in each of the domains and tests examined in this report.

Figure 2: Australian jurisdictional means with confidence intervals for PISA 2006



In relation to the total test, Queensland students performed better than students in Victoria, Tasmania and the Northern Territory but not as well as students in New South Wales, South Australia, Western Australia and the Australian Capital Territory.

Figure 3: Australian jurisdictional means with confidence intervals for *Identifying scientific issues* from PISA 2006

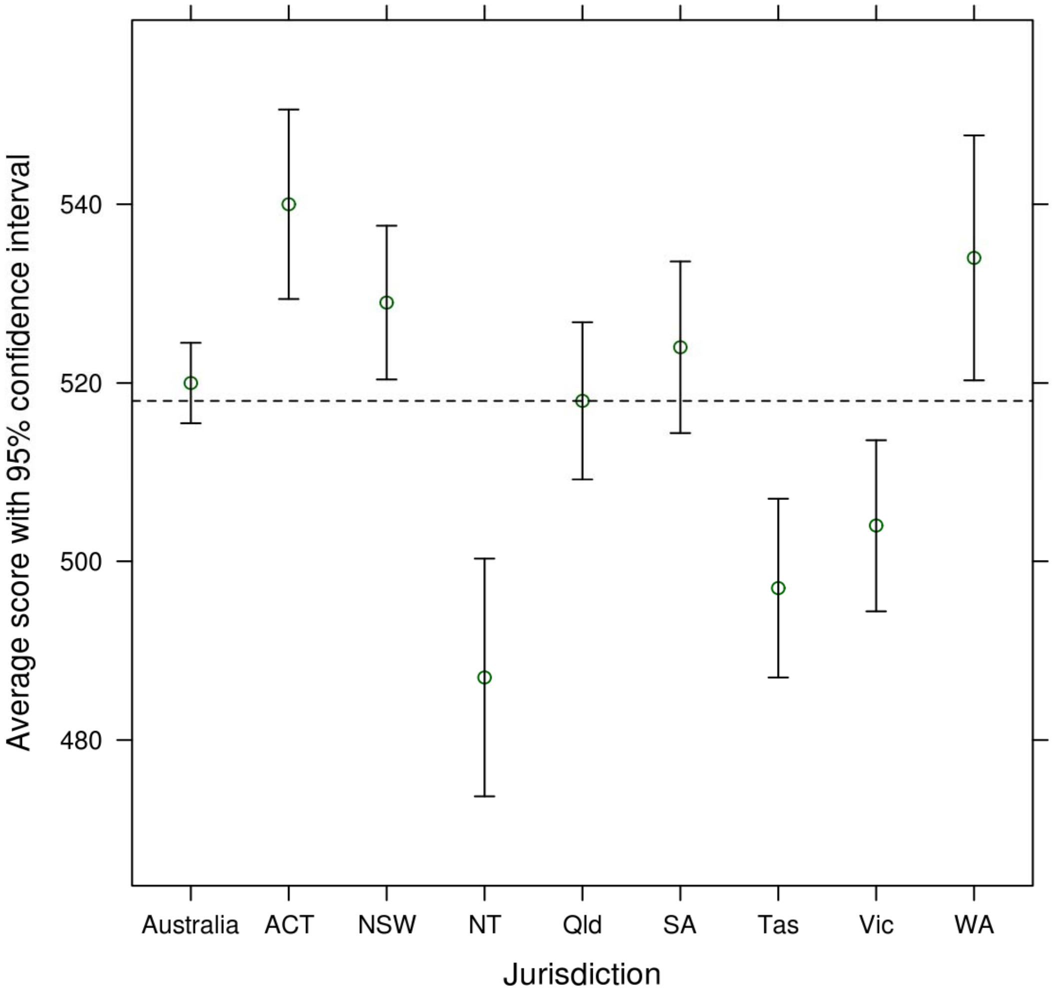


Identifying scientific issues incorporates the following skills:

- Recognising issues that are possible to investigate scientifically
- Identifying keywords to search for scientific information
- Recognising the key features of a scientific investigation.

In this domain the results for New South Wales, South Australia, Tasmania and Victoria overlap more significantly with the Queensland outcomes. This domain showed less difference between jurisdictions than others.

Figure 4: Australian jurisdictional means with confidence intervals for *Explaining phenomena scientifically* from PISA 2006

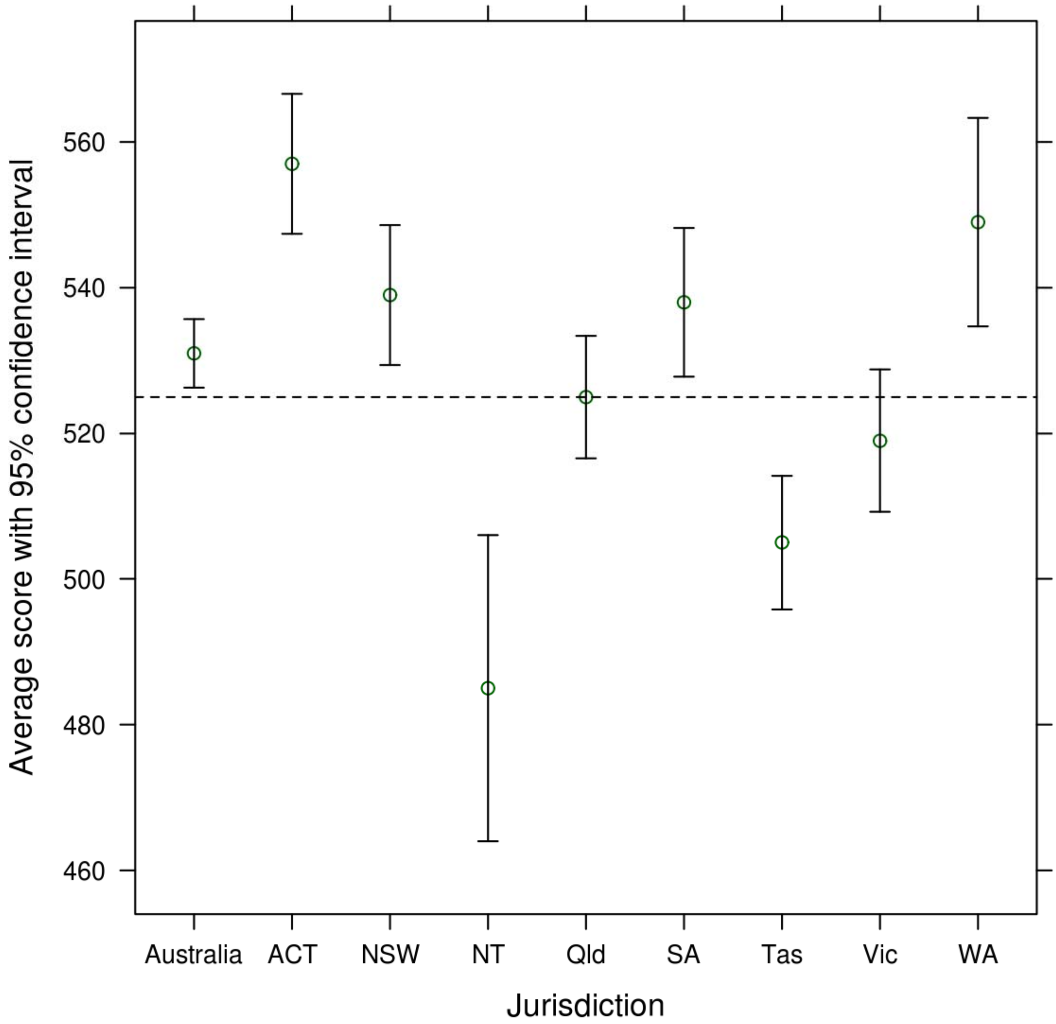


Explaining phenomena scientifically incorporates the following skills:

- Applying knowledge of science in a given situation
- Describing or interpreting phenomena scientifically and predicting changes
- Identifying appropriate descriptions, explanations, and predictions.

Queensland's relative placement compared to other jurisdictions is evident, and this domain is more consistent with the overall results than the *Identifying scientific issues* domain.

Figure 5: Australian jurisdictional means with confidence intervals for *Using scientific evidence* from PISA 2006



Using scientific evidence incorporates the following skills:

- Interpreting scientific evidence, and making and communicating conclusions
- Identifying the assumptions, evidence and reasoning behind conclusions
- Reflecting on the societal implications of science and technological developments.

Again, Queensland's relative placement compared to other jurisdictions is similar to the overall placement.

4.3 TIMSS 2007

TIMSS is sat by a sample of Year 4 and Year 8 student students every four years. The last of these was in 2007.

4.3.1 TIMSS 2007 Year 4

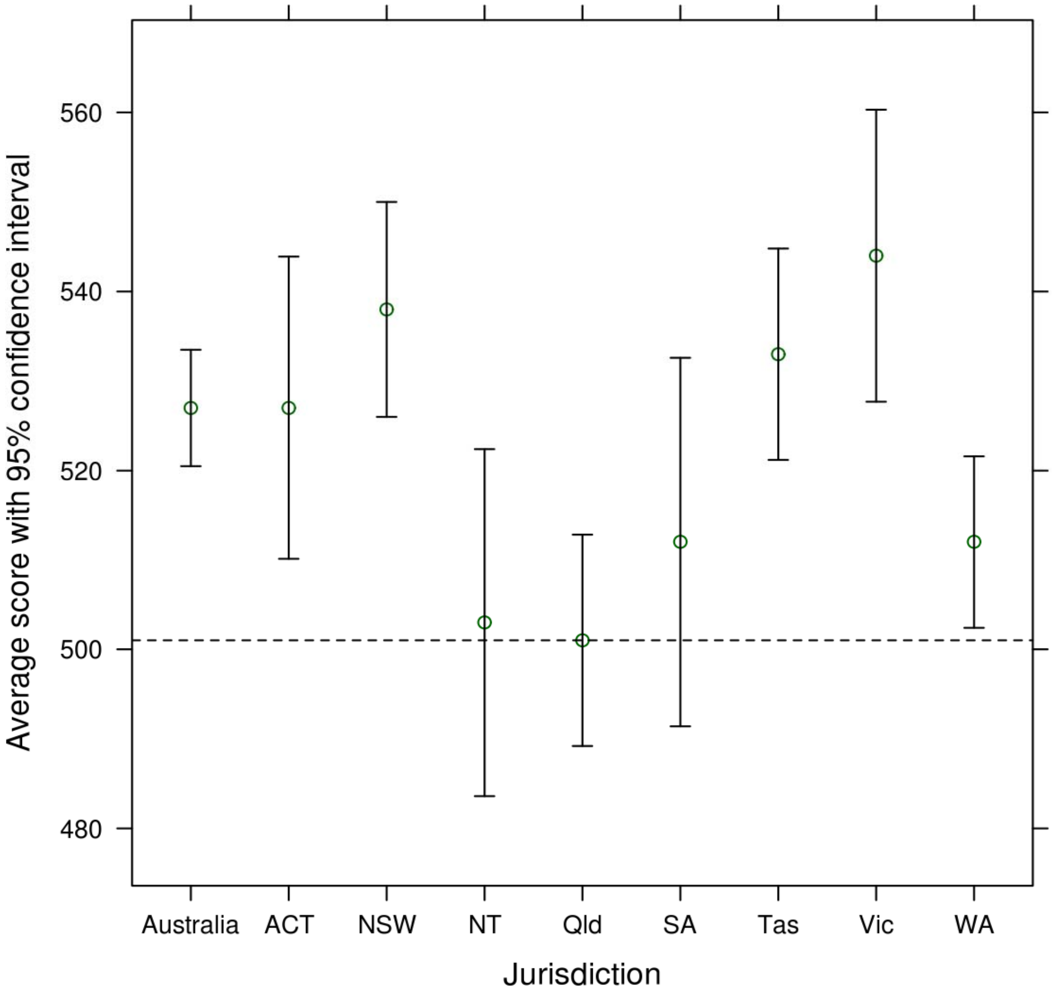
The following table summarises the seven domains of Science tested by TIMSS in 2007 for Year 4 students.

Table 3: Domains assessed by TIMSS 2007 Year 4

Content domains	Cognitive domains
Life Science Characteristics and life processes of living things Life-cycles, reproductions and heredity Ecosystems Human health	**Knowing** Recall/recognise Define Describe Illustrate with examples Use tools and procedures
Physical Science Classification and properties of matter Physical states Energy sources, heat and temperature Light and sound Electricity and magnetism Forces and motion	**Applying** Compare/contrast/classify Use models Relate Interpret information Find solutions Explain
Earth Science Earth's structure, physical characteristics and resources Earth's processes, cycles and history Earth in the solar system	**Reasoning** Analyse/solve problems Integrate/synthesise Hypothesise/predict Design/plan Draw conclusions Generalise Evaluate Justify
	Scientific inquiry Formulate questions and hypotheses Design investigations Represent data Analyse and interpret data Draw conclusions and develop explanations

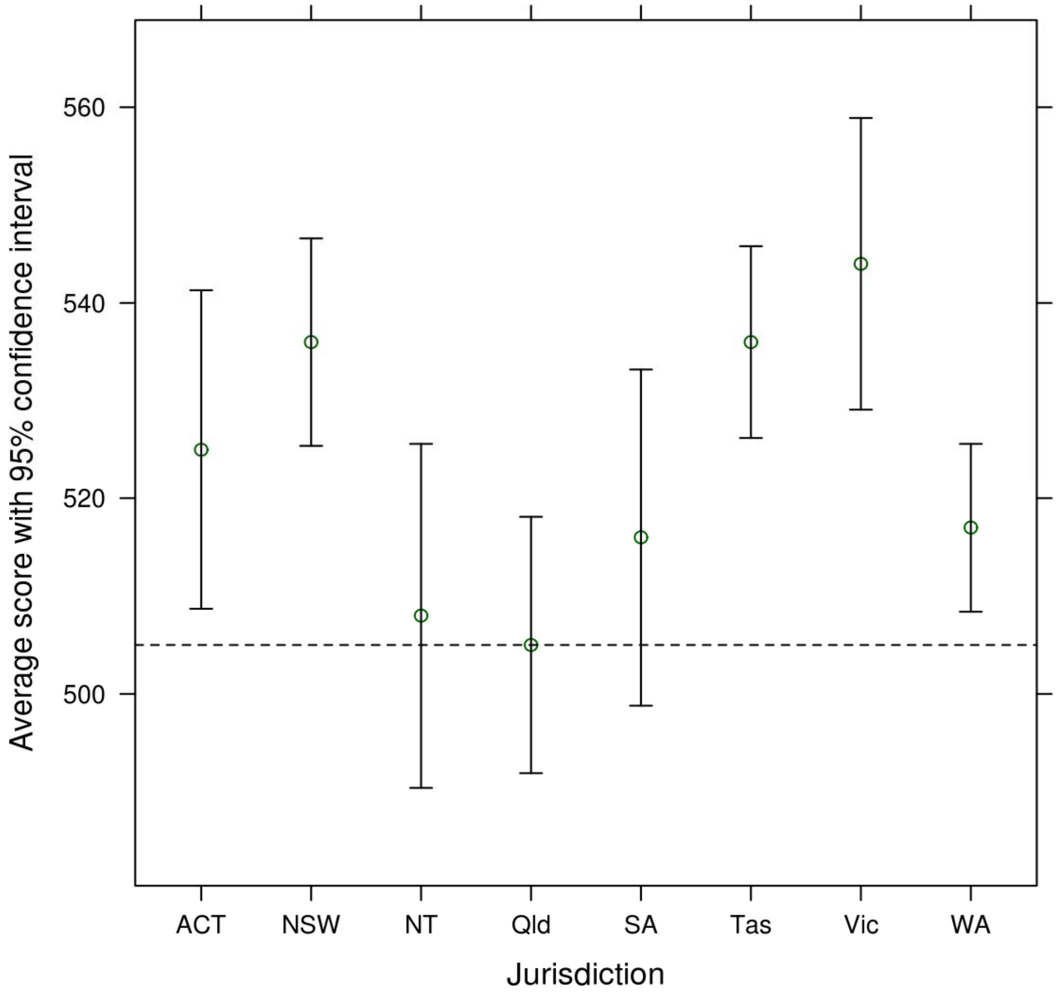
As was noted for the PISA assessments, Queensland's placement relative to other jurisdictions is relatively stable for all areas tested, as well as for the overall results.

Figure 6: Australian jurisdictional means reported confidence intervals from TIMSS 2007 Year 4



In relation to the total test score, Queensland Year 4 students performed as well as students in the Northern Territory but less well than students in all other states and the ACT. Although there is considerable overlap between Queensland's and South Australia's results, it is probable that the relative placement of the two jurisdictions has Queensland performing lower.

Figure 7: Australian jurisdictional means with confidence intervals for *Life Science* from TIMSS 2007 Year 4

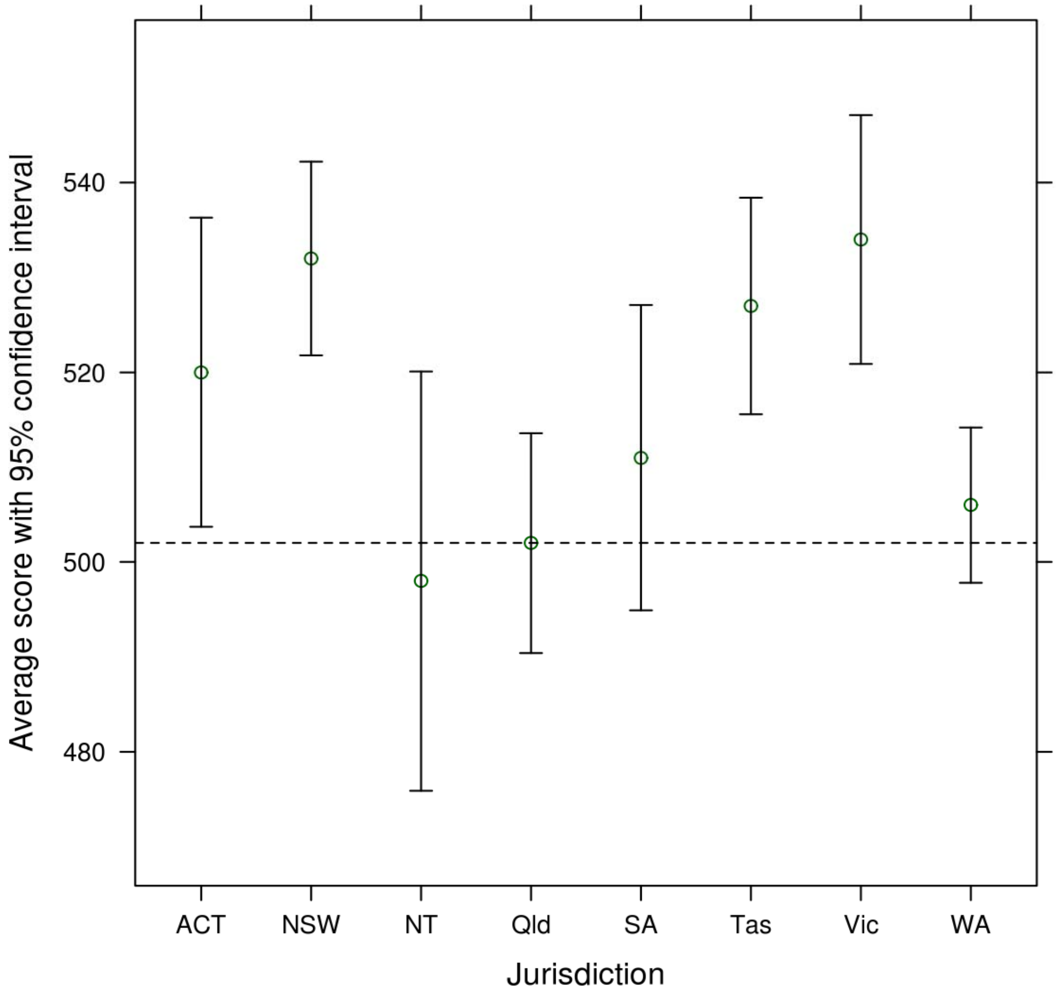


Life Science incorporates the following content:

- Characteristics and life processes of living things
- Life-cycles, reproduction and heredity
- Ecosystems
- Human health.

The placement of Queensland's result relative to those of other jurisdictions is similar to that in other domains.

Figure 8: Australian jurisdictional means with confidence intervals for *Physical Science* from TIMSS 2007 Year 4

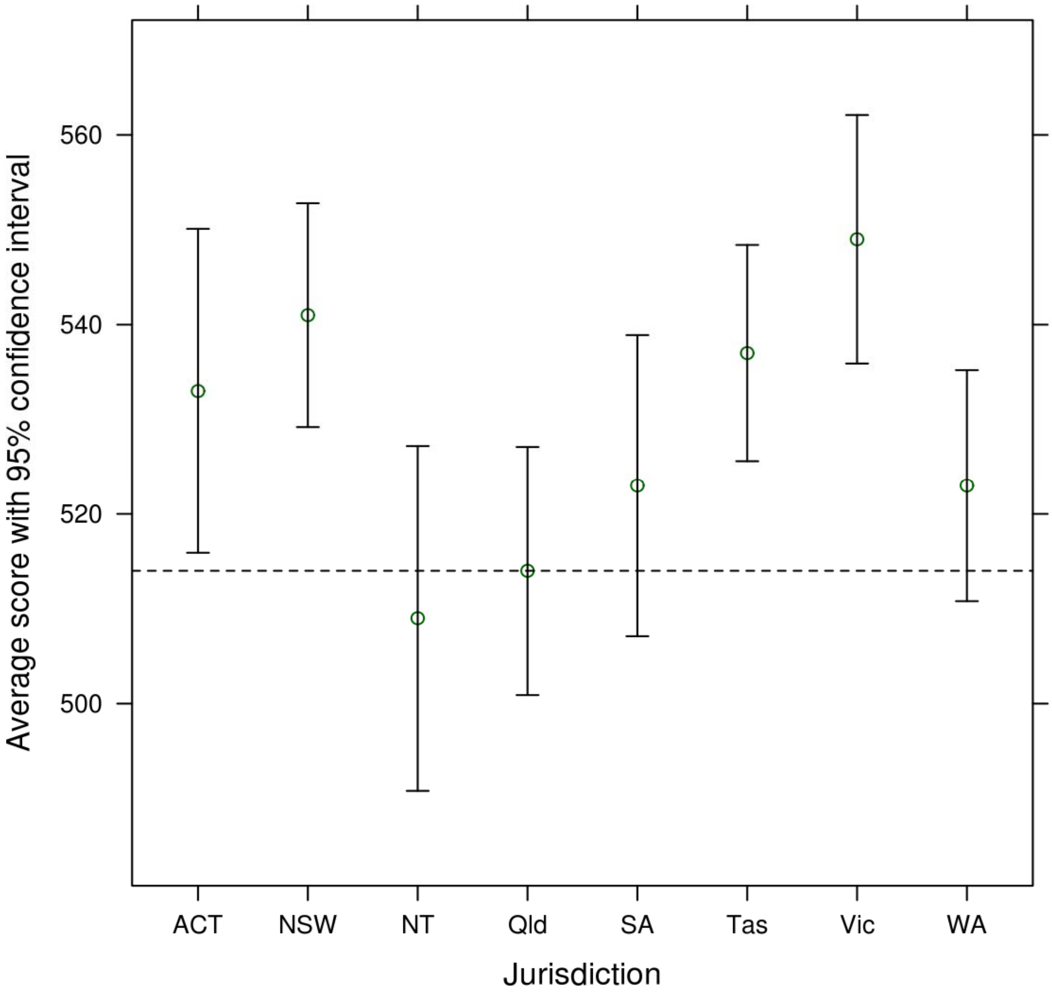


Physical Science incorporates the following content:

- Classification and properties of matter
- Physical states
- Energy sources, heat and temperature
- Light and sound
- Electricity and magnetism
- Forces and motion.

The placement of Queensland's result relative to those of other jurisdictions is similar to that in other domains.

Figure 9: Australian jurisdictional means with confidence intervals for *Earth Science* from TIMSS 2007 Year 4

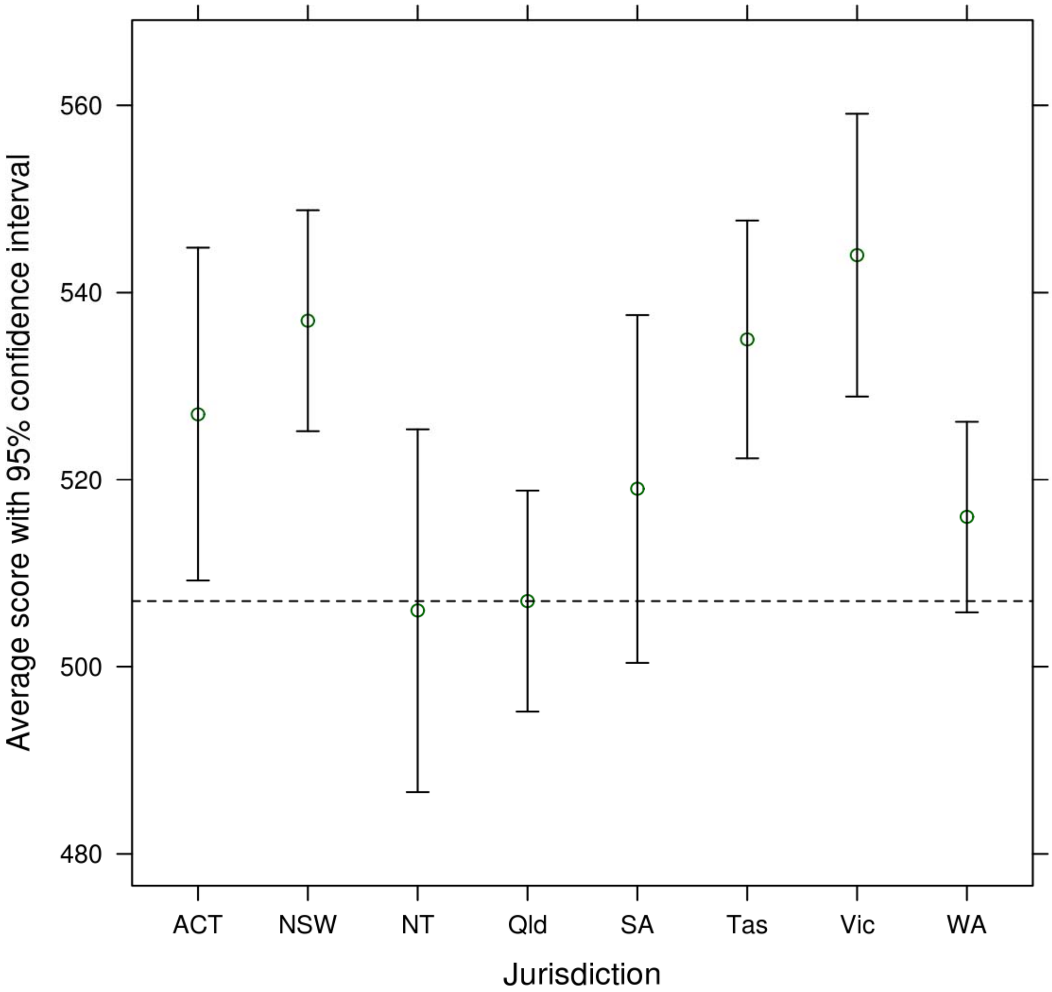


Earth Science incorporates the following content:

- Earth's structure, physical characteristics and resources
- Earth's processes, cycles and history
- Earth in the solar system.

Performance in this domain is slightly different, in that students from the Northern Territory do not appear to have achieved as well, but as was noted with the overall result, the considerable overlap suggests that there is no significant difference between the performances of students from the Northern Territory and Queensland.

Figure 10: Australian jurisdictional means with confidence intervals for *Knowing* from TIMSS 2007 Year 4

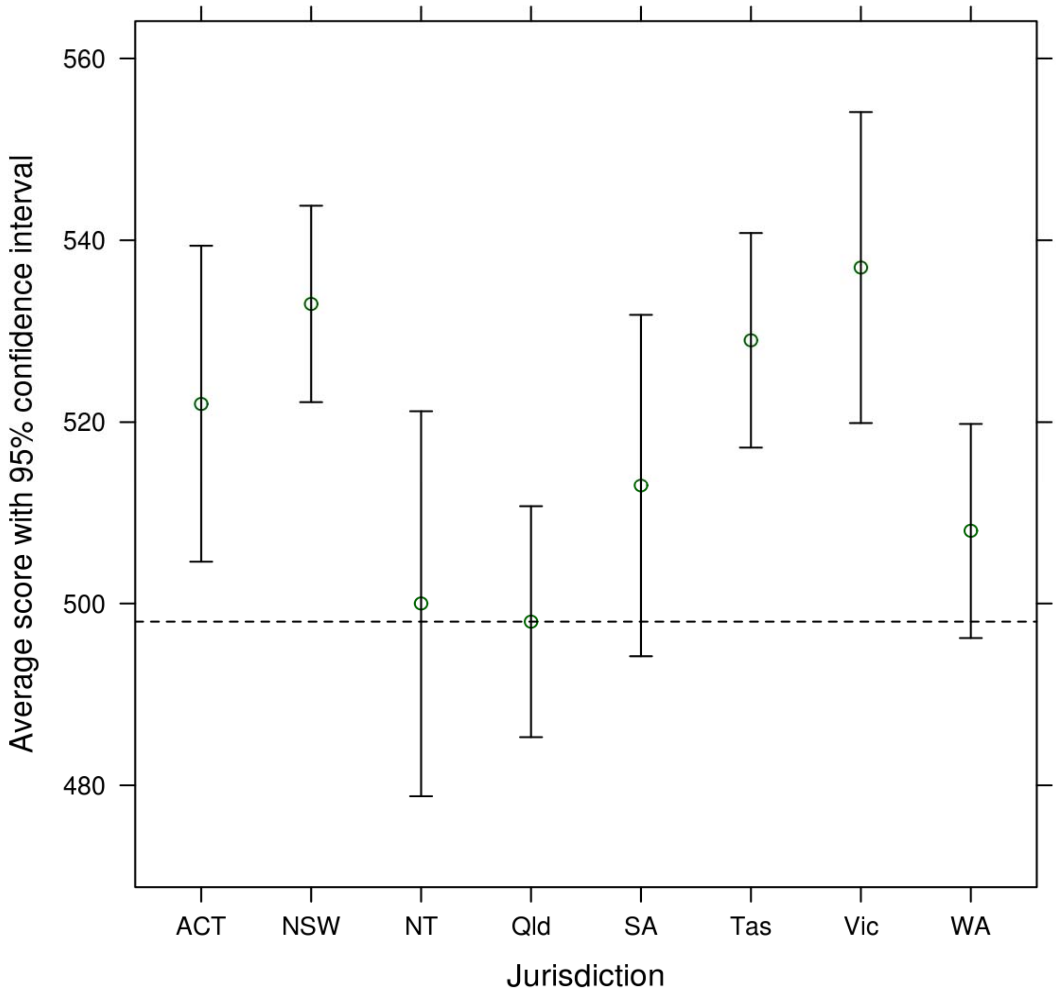


Knowing requires students to use the following cognitive skills:

- Recall/recognise
- Define
- Describe
- Illustrate with examples
- Use tools and procedures.

The placement of Queensland's result relative to those of other jurisdictions is similar to that in other domains.

Figure 11: Australian jurisdictional means with confidence intervals for *Applying* from TIMSS 2007 Year 4

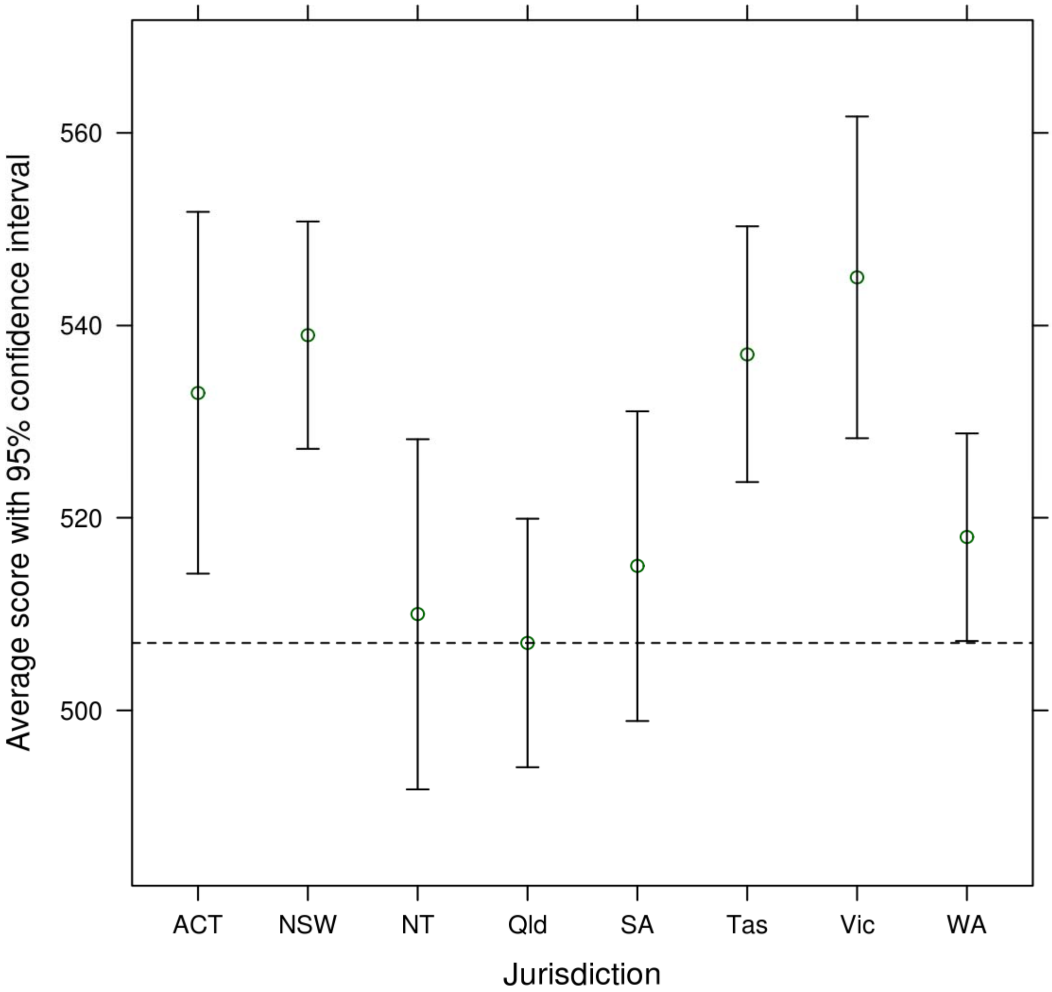


Applying requires students to use the following cognitive skills:

- Compare/contrast/classify
- Use models
- Relate
- Interpret information
- Find solutions
- Explain.

The placement of Queensland's result relative to those of other jurisdictions is similar to that in other domains, but perhaps shows relative weakness in this area compared to other domains.

Figure 12: Australian jurisdictional means with confidence interval for *Reasoning* from TIMSS 2007 Year 4



Reasoning requires students to use the following cognitive skills:

- Analyse/solve problems
- Integrate/synthesise
- Hypothesise/predict
- Design/plan
- Draw conclusions
- Generalise
- Evaluate
- Justify.

The placement of Queensland's result relative to those of other jurisdictions is similar to that in other domains. Queensland students again demonstrated some relative weakness in this domain compared to others.

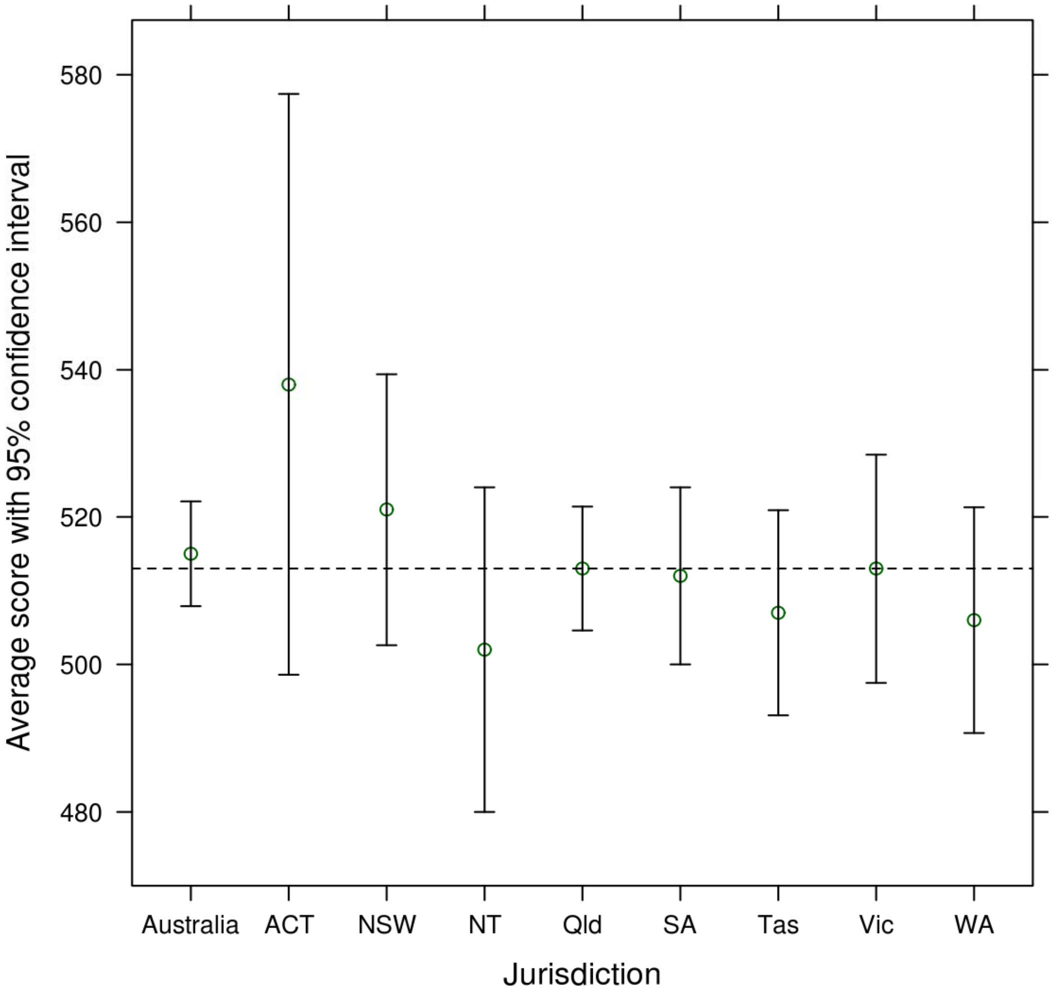
4.3.2 TIMSS 2007 Year 8

The following table summarises the eight domains tested by TIMSS in 2007 for Year 8 students.

Table 4: Domains assessed by TIMSS 2007 Year 8

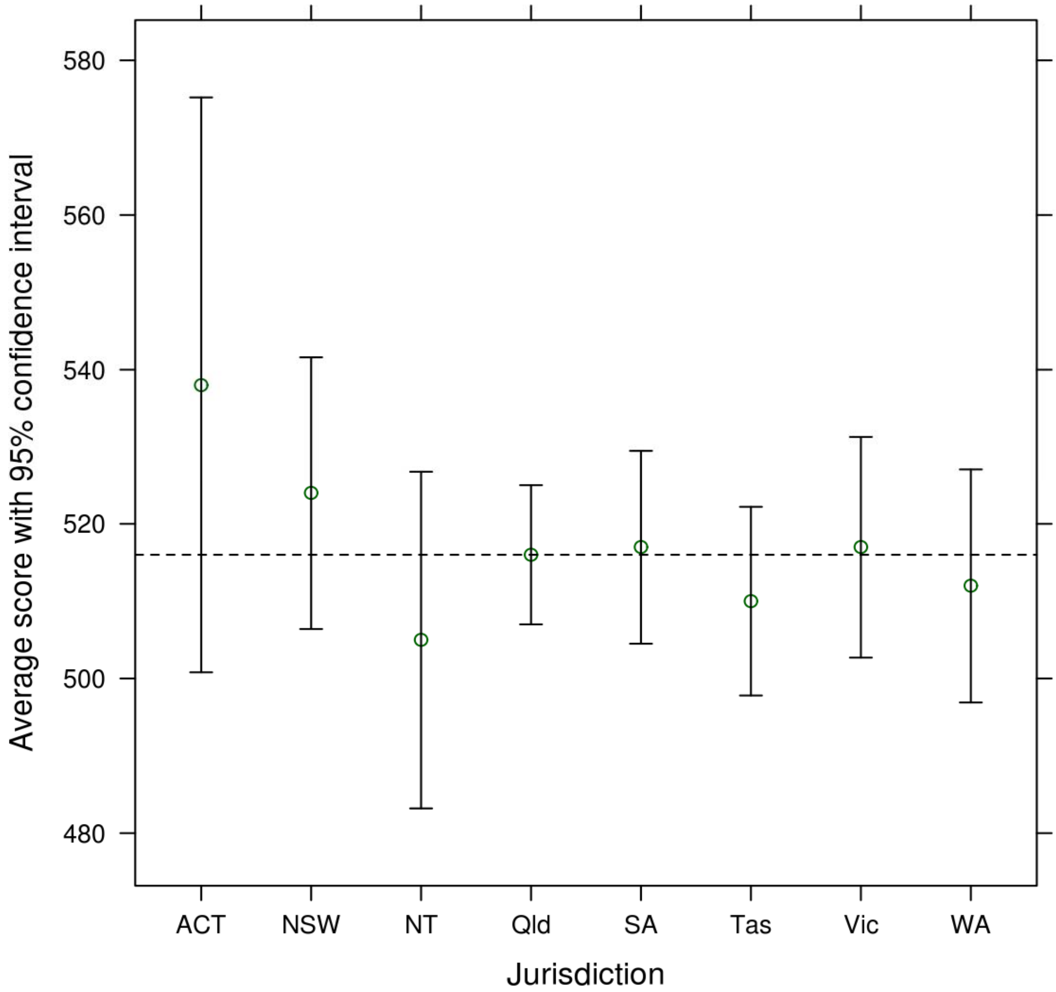
Content domains	Cognitive domains
Biology Characteristics, classification and life processes of organisms Cells and their functions Life cycles, reproduction and heredity Diversity, adaptation and natural selection Ecosystems Human health	**Knowing** Recall/recognise Define Describe Illustrate with examples Demonstrate knowledge of scientific instruments
Chemistry Classification and composition of matter Properties of matter Chemical change	**Applying** Compare/contrast/classify Use models Relate Interpret information Find solutions Explain
Physics Physical states and changes in matter Energy transformations, heat and temperature Light Sound Electricity and magnetism Forces and motion	**Reasoning** Analyse Integrate/synthesise Hypothesise/predict Design Draw conclusions Generalise Evaluate Justify
Earth Science Earth's structures and physical features Earth's processes, cycles and history Earth's resources, their use and conservation Earth in the solar system and the universe	**Scientific inquiry** Formulate questions and hypotheses Design investigations Represent data Analyse and interpret data Draw conclusions and develop explanations

Figure 13: Australian jurisdictional means with confidence intervals from TIMSS 2007 Year 8



After taking into account the confidence intervals, little difference can be seen between the jurisdictions. It could probably be said that Queensland students performed less well than those from New South Wales and the ACT but about the same as those from Victoria, South Australia, Western Australia, and Tasmania. Queensland students performed better than students from the Northern Territory.

Figure 14: Australian jurisdiction means with confidence intervals for *Biology* from TIMSS 2007 Year 8

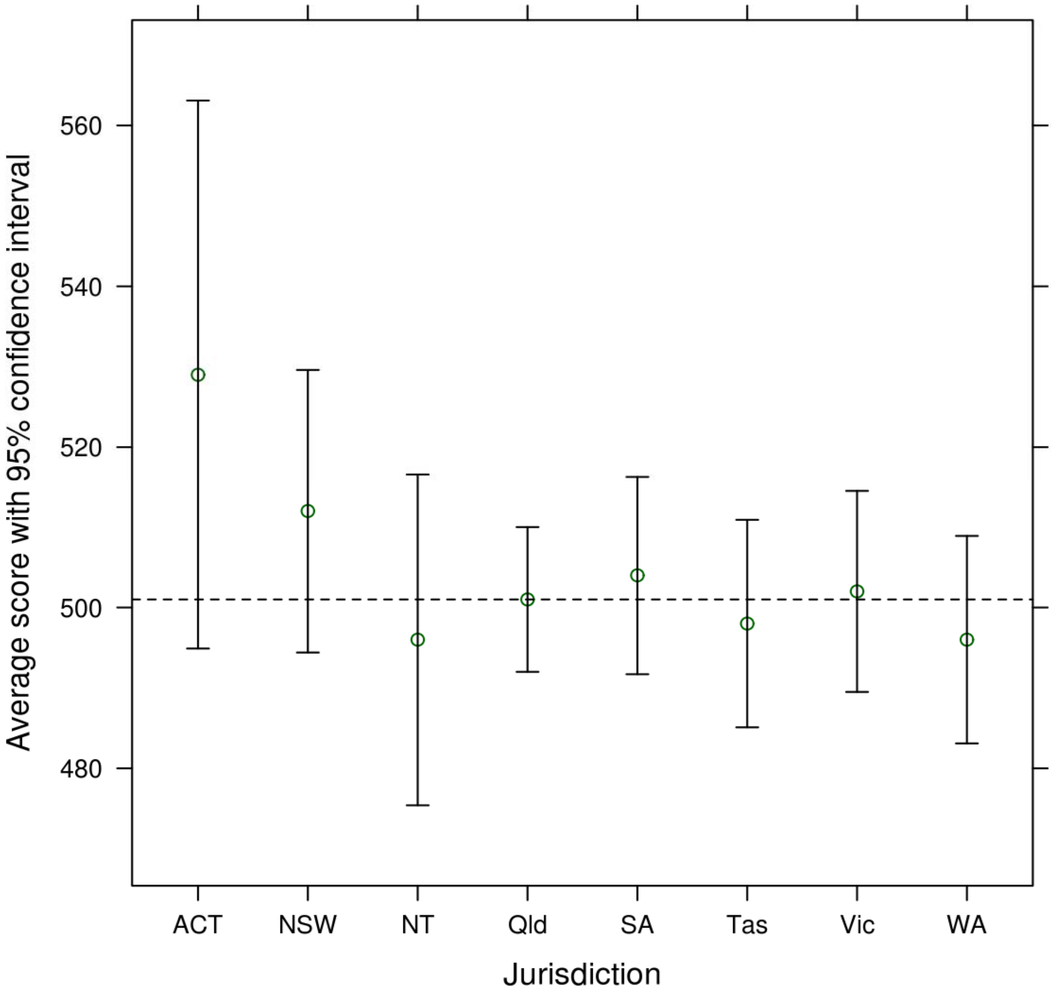


Biology incorporates the following content:

- Characteristics, classification and life processes of organisms
- Cells and their functions
- Life cycles, reproduction and heredity
- Diversity, adaptation and natural selection
- Ecosystems
- Human health.

The relative placement of Queensland students' performance to other jurisdictions is the same in the domains as in the overall results.

Figure 15: Australian jurisdictional means with confidence intervals for *Chemistry* from TIMSS 2007 Year 8

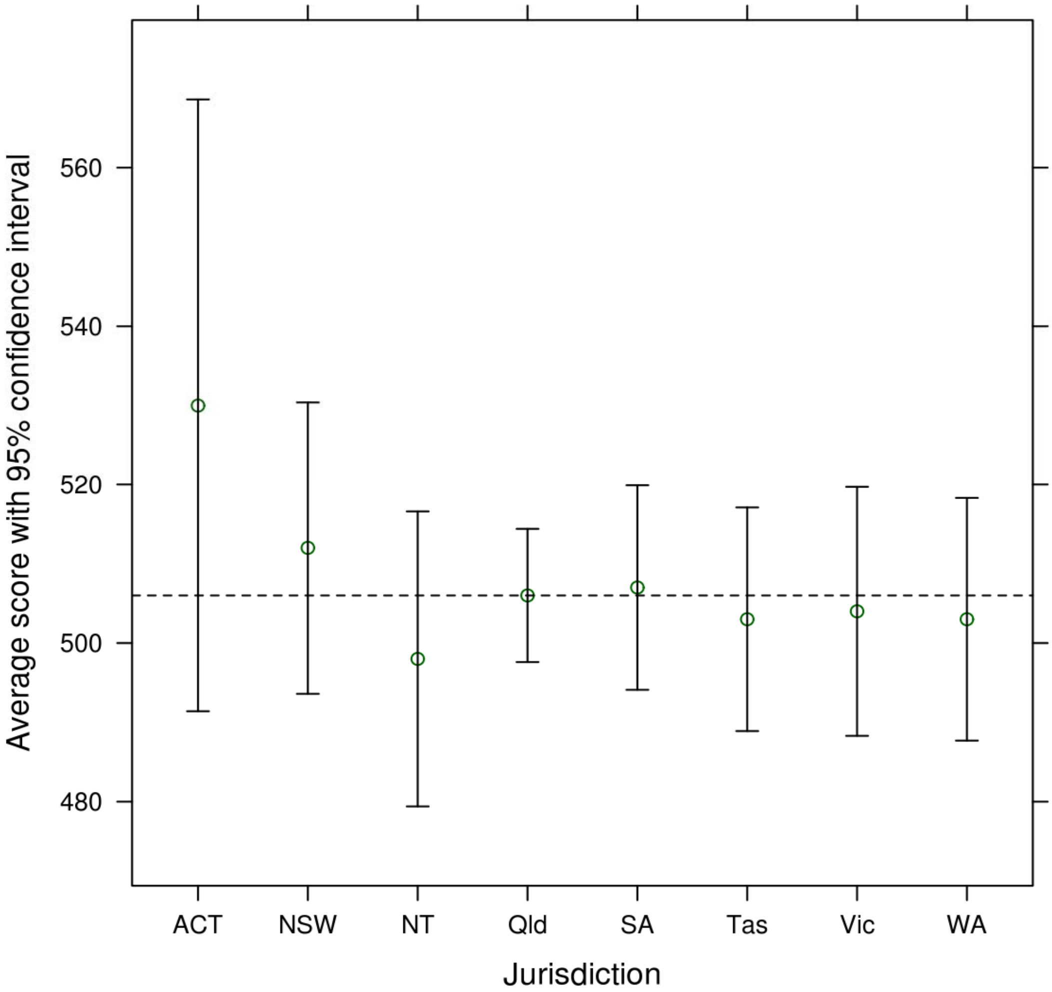


Chemistry incorporates the following content:

- Classification and composition of matter
- Properties of matter
- Chemical change.

The relative placement of Queensland students' performance to other jurisdictions is the same in the domains as in the overall results.

Figure 16: Australian jurisdictional means with confidence intervals for *Physics* from TIMSS 2007 Year 8

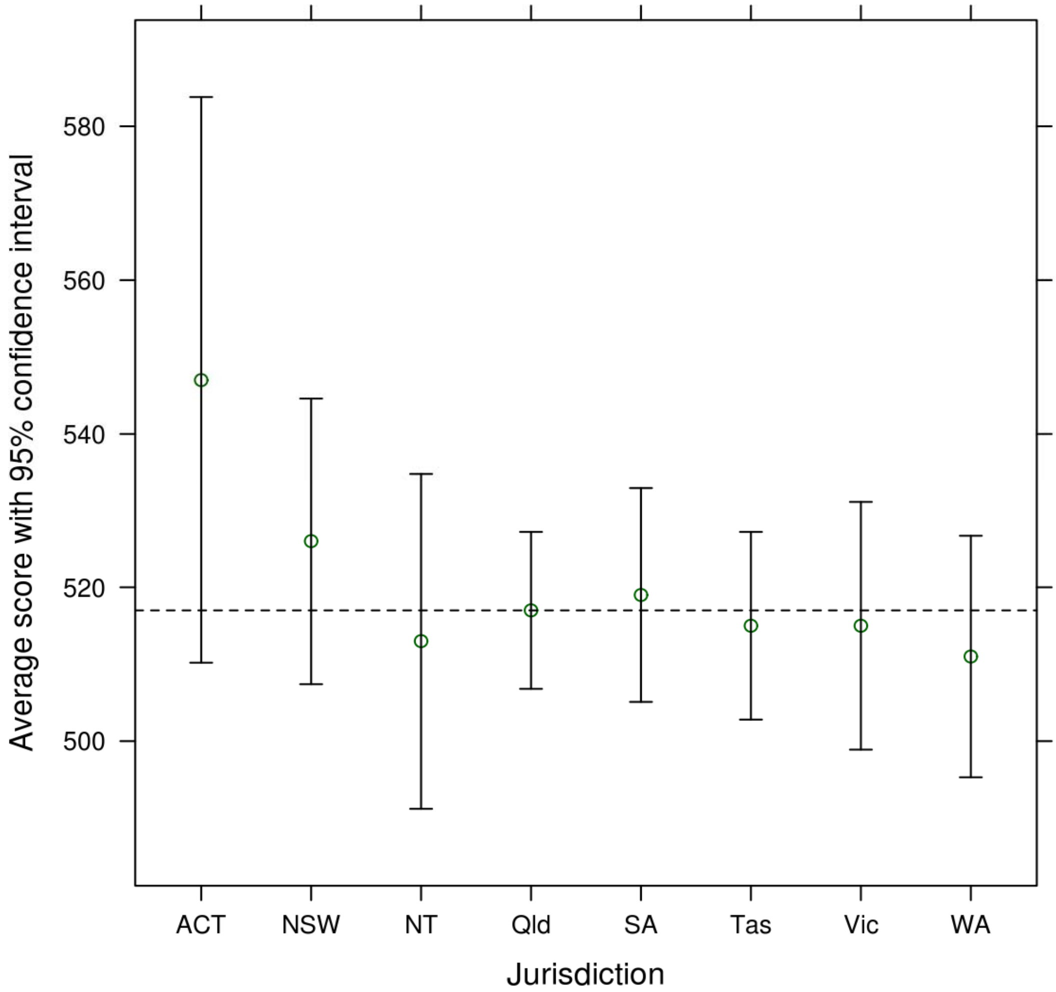


Physics incorporates the following:

- Physical states and changes in matter
- Energy transformations, heat and temperature
- Light
- Sound
- Electricity and magnetism
- Forces and motion.

The relative placement of Queensland students' performance to other jurisdictions is the same in the domains as in the overall results.

Figure 17: Australian jurisdictional means with confidence intervals for *Earth Science* from TIMSS 2007 Year 8

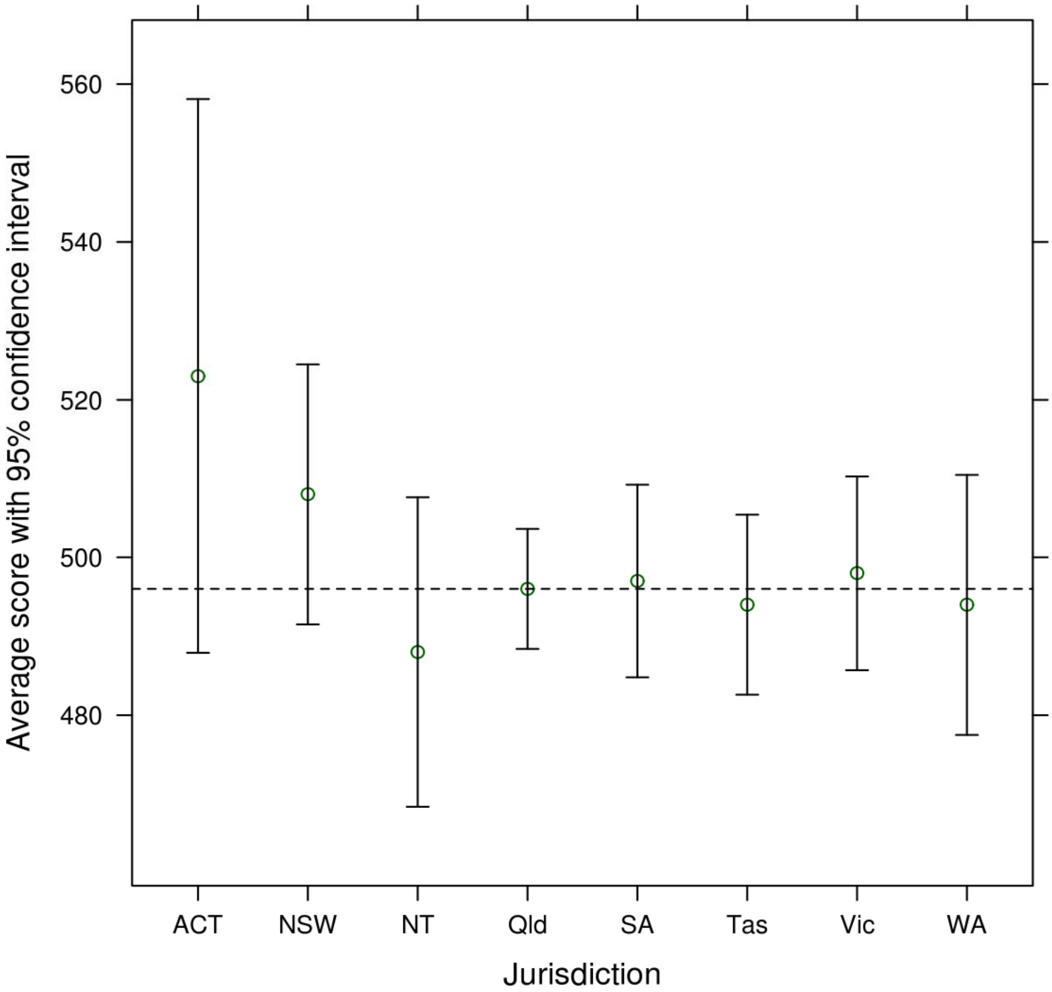


Earth Science incorporates the following:

- Earth's structures and physical features
- Earth's processes, cycles and history
- Earth's resources, their use and conservation
- Earth in the solar system and the universe.

The relative placement of Queensland students' performance to other jurisdictions is the same in the domains as in the overall results. There is some suggestion that Queensland is slightly higher in this domain than others, but the differences are certainly not statistically significant.

Figure 18: Jurisdictional means with confidence intervals for *Knowing* from TIMSS 2007 Year 8

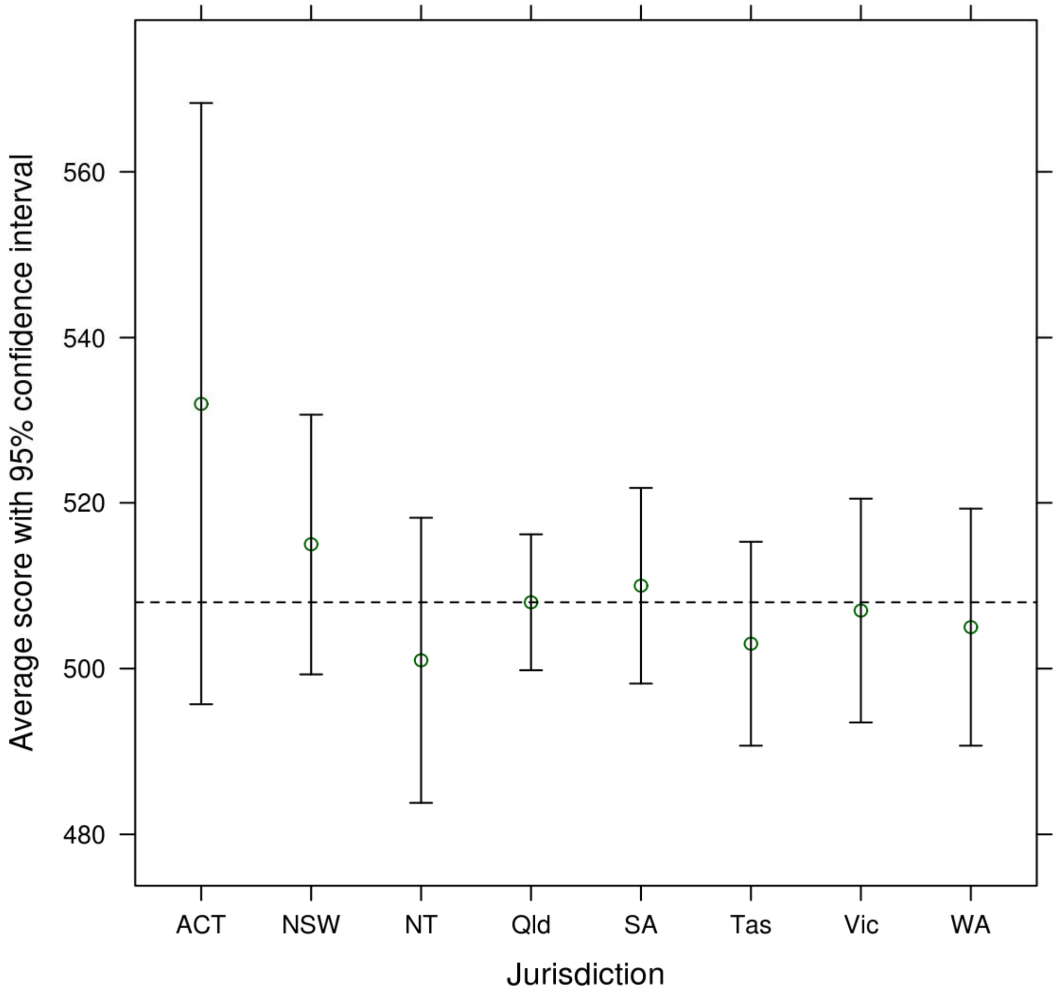


Knowing incorporates the following cognitive skills:

- Recall/recognise
- Define
- Describe
- Illustrate with examples
- Demonstrate knowledge of scientific instruments.

The relative placement of Queensland students' performance to other jurisdictions is the same in the domains as in the overall results.

Figure 19: Australian jurisdictional means with confidence intervals for *Applying* from TIMSS 2007 Year 8

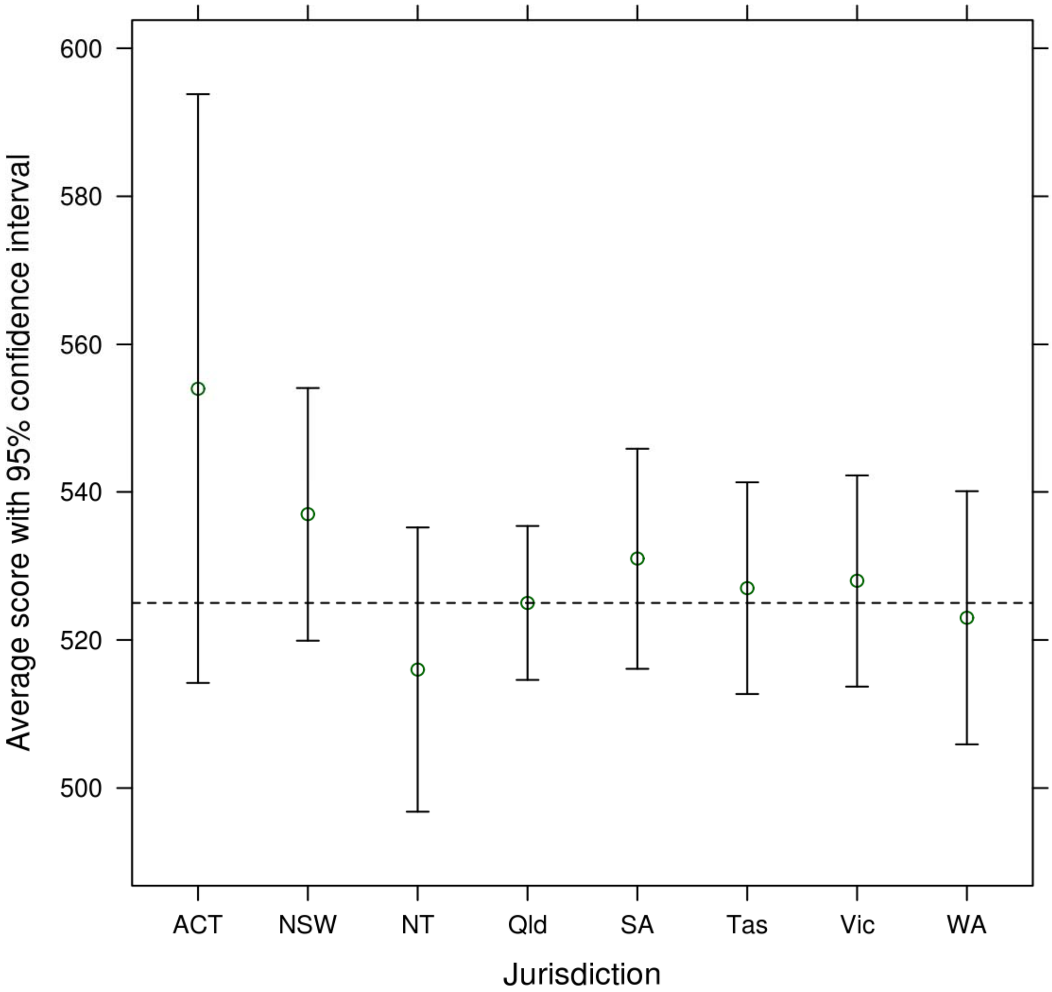


Applying incorporates the following cognitive skills:

- Compare/contrast/classify
- Use models
- Relate
- Interpret information
- Find solutions
- Explain.

The relative placement of Queensland students' performance to other jurisdictions is the same in the domains as in the overall results.

Figure 20: Australian jurisdictional means with confidence intervals for *Reasoning* from TIMSS 2007 Year 8



Reasoning incorporates the following cognitive skills:

- Analyse
- Integrate/synthesise
- Hypothesise/predict
- Design
- Draw conclusions
- Generalise
- Evaluate
- Justify.

This domain shows a slightly different pattern to other strands, and suggests some messages for teaching. Victorian and South Australian students' results are a little stronger, and Queensland students' results are more comparable to students in Western Australia and Tasmania than in other domains. However, these differences are not statistically significant and need to be treated cautiously.

5. Overview of the results

When considering the individual tests, one of the most striking results is that, within each assessment, there is little variation in the relative results of jurisdictions in each of the domains or areas being tested. This suggests that the correlation of scores between domains or areas is very high — students who score well do so consistently in each domain.

An internal scan of the questions that were available against the categories that were used often revealed that items had the potential to be categorised in multiple ways, or that there was some uncertainty about the match between the skills being tested and the categories. This is often the case with test items — it is rare that they neatly assess just one skill, domain or area.

The analysis indicates that there are few areas where Queensland students are clearly weak and where there is an obvious strategy for redressing these weaknesses. The only areas that suggest some slightly differential performance are:

- Year 4 in the domains of *Applying* and *Reasoning*
- Year 8 in the domain of *Reasoning*.

When considering performance across the science testing regimes a noticeable trend appears:

- In Year 4, Queensland students' mean scores rank close to equal last with the Northern Territory.
- In Year 6, four jurisdictions' results rank ahead of Queensland, two are equal and one is below.
- By Year 8, however, only two jurisdictions' results rank ahead of Queensland; two are equal and three are below.
- While Year 10 and 11 results should be interpreted cautiously in this context, because the testing takes place on an age group (15-year-olds) rather than a year level, on this test Queensland results rank between those of New South Wales and Victoria, both of which have larger and more metropolitan populations than Queensland.

This improvement in results as students get older is reflected in another widespread testing regime — the National Assessment Program — Literacy and Numeracy. Queensland students' results are clearly behind those of other jurisdictions except for the Northern Territory in Year 3, but by Year 9 they are roughly the same as or ahead of other jurisdictions except for New South Wales, Victoria and the ACT.

In terms of informing professional development, this suggests that science teaching in Prep – Year 6 should be particularly targeted.

6. Recommendations for professional development

The intent of this analysis was to examine Queensland students' performance in national and international tests and determine the areas in which they did not perform as well as students in other jurisdictions. Professional development could then target these areas.

Recommendation 1

That professional development be targeted at teachers of P — Year 6.

The analysis reveals that the area of greatest weakness is in the lower to mid primary years (up to Year 6). This would come as no surprise to researchers in the field of science education, since this period of schooling is most frequently identified as the time when negative attitudes to science teaching and learning can be established.

At this stage of schooling, research has identified that science teaching is least effective. This is generally attributed to teachers of these years having less content knowledge than is needed to teach the subject effectively. Primary teachers have identified science as a content area in which they lack confidence (Hackling 2006) and consequently score poorly on self-efficacy scales that measure the extent to which primary teachers feel capable of teaching science effectively (Riggs & Enochs 1990).

Recommendation 2

That professional development focus on developing content knowledge and pedagogical content knowledge.

To do this, professional development should include the following strategies:

- short, focused sessions aimed at building content knowledge and ensuring an alignment between the intended and the enacted curriculum, including some emphasis on Life Sciences.
- longer sessions that follow up on these content sessions with ideas about delivery, development of higher order thinking skills and assessment in science, in particular:
  - how to apply this knowledge to develop cognitive skills:
    - knowing (recall/recognise, define, describe, illustrate with examples, use tools and procedures)
    - applying (compare/contrast/classify, use models, relate, interpret information, find solutions, explain)
    - reasoning (analyse/solve problems, integrate/synthesise, hypothesise/predict, design/plan, draw conclusions, generalise, evaluate, justify).
- networking sessions with teachers from the same years where horizontal learning can take place
- collaborative or collegial coaching, where teachers are able to help each other develop skills and knowledge without fear that they are being judged by a superior.

Professional development could be best targeted towards developing content knowledge and developing teaching strategies towards the higher order cognitive skills.

The literature suggests that teachers lack pedagogical content knowledge, that is, they lack the means to teach what they do know in interesting and engaging ways. They also lack confidence with the content knowledge and this restricts teaching higher order thinking areas. Shulman (1986) argues that teachers require an equal balance in knowledge about how to teach, what to teach and why to teach it.

In order to engage teachers in the lower primary years in more effective teaching of science there is a need to reflect on the purposes for science as a discipline. The emphasis among scientists is not on the discipline itself but on the need to develop a scientific literacy that would give students the ability to see the importance of science in their world (Fittell 2008; Van Driel, Beijaard & Verloop 1999; Goodrum & Rennie 2007).

The development of scientific literacy is a far wider view than some science teachers have, particularly in the secondary years where they see the purpose of teaching science as preparing students for university studies in science. Scientific literacy and fostering a genuine love of learning about science is encouraged through inquiry-based learning and open-ended problem solving. Contemporary science education aims to use knowledge in authentic contexts. Science educators argue that a focus on examining ideas, evidence and argumentation in science classes has the potential to improve conceptual understanding, enhance critical thinking and reasoning, develop a deeper understanding of the nature of science, and make learning science more enjoyable (Tytler 2007). This offers an education that is more appropriate to the needs of future citizens. Tytler says: “Knowledge is not only needed for understanding and explaining phenomena, but it underpins understanding of investigative processes and the nature of science” (2007: p 42).

This purpose of science education is broader than preparing students to perform well on a pencil and paper test, an aim that could limit the science curriculum in ways that would not encourage a love of and interest in science in an engaging way (Fensham 2009). This is especially relevant when we consider the need for balance between positivist and constructivist learning paradigms. The pen and paper, point in time test — if it becomes the focus of learning — will tend to encourage the positivist approach, in which there is a correct answer.

These changes to the purpose of science education — and the corresponding focus on students learning science through inquiry, and on teaching science as contextualised and interdisciplinary (Tytler 2007) — require an associated change in pedagogy and assessment, which in turn needs to be supported through professional development programs for teachers.

Professional development should increase teachers’ capacity to develop appropriate teaching and learning opportunities. Sessions in which teachers can exchange ideas and experiences are crucial in developing better content and pedagogical knowledge. While there are several very good resources available online, it is important that teachers do not feel that they can rely on them alone, to the extent that they fail to develop their own resources and teaching methods (De Laat & Watters 1995; Fittell 2008). Over-reliance on a particular resource results in discrepancies between the intended curriculum and the enacted curriculum.

Any professional development program should include the following areas, in which the analysis in section 4.3.1 indicated some weakness:

- Life Science
- the domains of Applying and Reasoning.

Recommendation 3

That professional development for teachers of science be aligned with the implementation of the Australian Curriculum.

To be enacted through:

- development of a “science learning continuum” or mapping of P–10 achievement standards outlined in the Australian Science Curriculum as year-level milestones or aspirational targets
- continued development of science items in the Assessment Bank “tagged” to this science learning continuum
- continued implementation of science Queensland Comparable Assessment Tasks (QCATs) “tagged” to this science learning continuum.

The implementation of the Australian Curriculum will mean some change for all teachers. Aligning professional development for science with the implementation of the Australian Curriculum would provide a meaningful context in which teachers could re-examine their content knowledge and find ways to build their pedagogical content knowledge.

One way of effectively aligning the K–10 Australian Curriculum in Science with existing curriculum and resources is through the development of a “science learning continuum” or mapping of K–10 achievement standards in the Australian Curriculum in Science as year-level milestones or aspirational targets.

The growing number of science items in QSA’s Assessment Bank and future science QCATs (Queensland Comparable Assessment Tasks) would be “tagged” to this science learning continuum to assist teachers in ensuring that opportunities for growth and development in students’ learning in science are provided in a systematic manner.

Recommendation 4

That the findings of this report inform current and planned school sector support and school leadership.

School sectors are already undertaking professional development to support the teaching of science. These activities are outlined in Appendix 2. It is recommended that schooling sectors work with the QSA to use the data in this report when planning future professional development initiatives.

Research has shown that even though science has been identified as a key area of learning, the teaching of science in primary schools does not have an equivalent level of emphasis, with the second lowest allocation of time in the primary school curriculum of 2.7 per cent. (Hackling 2006). Strong instructional and discipline leadership within schools to help develop teachers’ knowledge, skills and attitudes to science teaching and learning must complement any professional development to build teachers’ content and pedagogical content knowledge. Additional human resources to support the management of practical activities would support teachers by providing time to focus on content and pedagogical content knowledge acquisition as opposed to using time to gather and prepare physical resources and equipment.

Recommendation 5

That providers of pre-service primary teacher education prepare teachers better by placing a greater focus on science content and pedagogical content knowledge.

The limited science discipline studies and science curriculum studies in many Australian teacher pre-service education programs (Lawrance & Palmer 2003) give student teachers little opportunity to build the pedagogical content knowledge (Gess-Newsome 1999) required to be confident and effective teachers of science.

Teachers need to conceptualise the subject matter from multiple perspectives and at a much deeper level if they are to communicate an accurate understanding of scientific knowledge to students. Such knowledge is essential in order to teach for understanding and to provide authentic learning opportunities for students, including the use of an inquiry model for the teaching and learning of science (Tairab 2010).

Studies that have focused on disciplinary content knowledge indicate that teachers with more content knowledge tend to teach in ways that will allow students to construct knowledge and develop science ideas conceptually. If a teacher holds an incorrect idea students are more likely to develop the same incorrect idea than if the teacher held the correct idea.

7. Conclusion

Professional development opportunities must be seen by teachers as authentic and valuable, otherwise funding and resources will be largely wasted and student performance will not improve.

The Math and Science Partnership <www.mspkmd.net> provides insights from practitioners with diverse backgrounds and experiences, working with teachers to develop advice for designing professional development programs to support teachers to deepen their science content knowledge. This advice includes:

- consider how deeply each goal of the program needs to be pursued, as it is not possible to “achieve it all”
- choose professional development strategies that align with the content, audience and goal/s
- provide multiple opportunities for teachers to explore new and difficult ideas and concepts
- design the professional development activities so they are accessible and challenging with a range of science understandings
- consider how each of the professional development opportunities fits together in order to deepen teacher knowledge and skills.

The findings from this analysis of Queensland students’ performance in national and international science tests provide a place to start when considering systemic professional development in science.

References

Australian Curriculum, Assessment and Reporting Authority 2009, *National Report: Achievement in reading, writing, language conventions and numeracy 2009*. ACARA. Accessed 3 Nov 2010, <www.naplan.edu.au/reports/national_report.html>

Australian Curriculum, Assessment and Reporting Authority 2010 *2009 National Assessment Program — Science Literacy Report.* ACARA. Accessed 6 April 2011, <www.mceecdya.edu.au/verve/_resources/NAP-L_2009_PublicReport_HighRes.pdf>

De Laat, J & Watters, JJ 1995, "Science teaching self-efficacy in a primary school: A case study", *Research in Science Education*, vol. 25, iss. 4, pp. 453–64.

Fensham, PJ 2009, "The link between policy and practice in science education: The role of research", *Science Education*, vol. 93, iss. 6, pp. 1076–95.

Fensham, PJ & Maxwell, GS 2008, *How Well Prepared: What PISA 2006 revealed about Queensland 15 year olds*, State of Queensland, Department of Education, Training and the Arts.

Fittell, D 2008, "Reforming primary science education: Beyond the 'stand and deliver' mode of professional development", paper presented at *Changing Climates: Education for Sustainable Futures,* the Australian Association for Research in Education Conference, Queensland University of Technology, Brisbane, 30 Nov – 4 Dec 2008.

Gess-Newsome, J 1999, "Expanding questions and extending implications: A response to the paper set", *Science Education*, vol. 83, iss. 3, pp. 385-391.

Goodrum, D & Rennie, LJ 2007, *Australian School Science Education National Action Plan 2008-2012 Vol. 1.*, Commonwealth of Australia, Department of Education, Science and Training, Canberra.

Hackling, M 2006, "Primary Connections: A new approach to primary science and to teacher professional learning", paper presented at *Boosting Science Learning —What will it take?, the* ACER conference, Canberra, 13–15 Aug 2006..Accessed 3 Nov 2010, <http://research.acer.edu.au/research_conference_2006/14>

Lawrance, GA & Palmer, DH 2003 *Clever Teacher, Clever Sciences: Preparing teachers for the challenge of teaching science, mathematics and technology in 21st century Australia*, Canberra: Commonwealth of Australia, Department of Education, Science and Training, Evaluations and Investigations Program, vol: 03/06, Canberra.

Masters, GN 2009 A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools, Australian Council for Education Research, (ACER) press.

Matters, G 2006 *Assessment Approaches in Queensland Senior Science Syllabuses*, Australian Council for Education Research, (ACER) press.

Minstrell, J & van Zee, EH 2000, *Inquiring into Inquiry Learning and Teaching in Science*, American Association for the Advancement of Science, Washington DC.

National Science Foundation, *Mathematics and Science Partnership* website. Accessed 15 Sep 2010 <www.mspkmd.net>.

Riggs, IM & Enochs, LG 1990 "Toward the development of an elementary teacher's science teaching efficacy belief instrument", *Science Education*, vol. 74, iss. 6, pp. 625–37.

Shulman, LS 1986 "Those who understand: Knowledge growth in teaching", *Educational Researcher*, vol. 15, iss. 2, p. 4–14.

Tairab, HD 2010, "Assessing science teachers' content knowledge and confidence in teaching science: How confident are UAE prospective elementary science teachers?" *International Journal of Applied Educational Studies*, vol. 7, iss. 1, p. 59.

Thomson, S & De Bortoli, L 2008, “Exploring Scientific Literacy: How Australia measures up”, *The PISA 2006 survey of students' scientific, reading and mathematical literacy skills*, Australian Council for Education Research, (ACER) press.

Tytler, R 2007, “Re-imagining Science Education: Engaging students in science for Australia's future”, *Australian Education Review No. 51*. Australian Council for Education Research, (ACER) press.

Van Driel, JH, Beijaard, D & Verloop, N 1999, “Professional development and reform in science education: The role of teachers’ practical knowledge”, *Journal of Research in Science Teaching*, vol. 38, iss. 2, pp. 137–58.

Appendix 1

Results of panelling of released items where Queensland underperformed, from NAP – Science Literacy 2006.

Item no.	Description of item skill	NAP 2006 item description
6	Locate information in a table	Compares aspects of data in simple supplied table of results
7	Using the process of elimination to find the only correct answer to match a set of facts correctly	Summarises patterns in the data to find common properties of plastics
14	Describe the differences between two drawings	Describes differences between objects (natural and synthetic fibres)
33	Knowledge of how the pitch of a vibrating string is affected by the physical properties of the string	Describe cause and effect relationship

Appendix 2

Current Science professional development programs in Queensland

Representatives of the three schooling sectors were contacted in order to ascertain what Science PD for teachers was currently occurring in each sector. Representatives from Independent Schools Queensland, Queensland Catholic Education Commission and the Department of Education and Training were interviewed. Summaries of the interviews are recorded below.

Independent Schools Queensland

Independent Schools Queensland (ISQ) is piloting a scheme related to *Primary Connections*. Six independent primary schools are developing units of work in primary science using both the *Primary Connections* model for unit planning and drawing from the draft Australian Curriculum content descriptions and achievement standards K-10. The schools will teach the units, assess students' achievements in the units and then engage in a social moderation exercise to establish comparable A–E grades. The moderation exercise has the potential for ISQ to develop meaningful A–E descriptors by having the teachers involved in the moderation exercise describe the difference in the work they judge as being A, B, C, D and E standards. The project is also important in giving primary teachers the confidence to apply the *Primary Connections* model for unit planning to their own pre-existing science units. ISQ will involve more schools in this exercise next year if there is funding available to extend the project

In the secondary area, six Queensland independent secondary schools are involved in a project to foster a more rigorous approach to inquiry and argumentation in secondary science. The project uses some of the same professional learning methodologies used in the "Science by Doing" pilot project funded originally by the Academy of Science. The six project schools are located on the Gold Coast and the teachers have been encouraged to work together as a professional learning community. ISQ provides the cluster of teachers with resources, strategies and ideas for improving the teaching of inquiry in their secondary science classrooms. The six project schools will be expected to share the outcomes of their project with a wider independent schools audience. Independent secondary schools are also involved in the Science and Technology Education Leveraging Relevance (STELR) program. Three of the approximately 20 schools in Queensland are independent schools. These schools will also share their experiences more broadly with representatives from across the sector at a forum next year.

ISQ has now secured Australian Government Quality Teacher Program (AGQTP) funds for 2011 and some of this funding will be used to engage a wider group of science teachers in the results of these projects.

ISQ supported the approach of working closely with the QSA to identify and target areas of relative underperformance in the science domains and ensure that science testing and PD are closely aligned to the new national science curriculum.

ISQ would welcome additional targeted science PD funding to enable ISQ schools to further contribute to improving students' science literacy performances in national and international tests across primary and secondary areas.

The Department of Education and Training

The Department of Education and Training (DET) has introduced two major PD programs in Science. These are outlined below.

Science Spark

Science Spark is an initiative to rejuvenate interest in science teaching and re-ignite student interest in the subject. It focuses on the enhancement of teacher capability in Years 4—7.

$37.7 million has been allocated over three financial years under the Queensland Government's Science Spark initiative to focus on enhancing the teaching of science in Years 4—7.

The funding consists of:

- $15.2 million for the professional development program focusing on improving teacher knowledge and skills to teach science
- $22.5 million for the 100 primary science facilitator (PSF) positions working with teachers and students in Years 4—7.

Fifteen regional managers (science) have been appointed and trained through Teaching and Learning Branch to deliver one full day of science professional development to every teacher of Years 4–7 in Queensland's state schools. They have begun delivery of a comprehensive professional development program, which will address the key messages of the Science Spark Initiative.

By June 2010 15% of Years 4–7 teachers will have received professional development, 60% by June 2011 and 100% by June 2012.

Principals will also be assisted by a program focusing on curriculum leadership that emphasises the significance of science education in the primary curriculum.

The key goals of the Science Spark program are to:

- increase teachers' scientific knowledge
- develop teachers' skills in the teaching of science
- enhance teachers' confidence in teaching science
- help teachers make learning science accessible and engaging
- improve student performance in science and help build a community with a high level of scientific literacy.

One hundred full-time equivalent science teachers are based in state schools in every region across Queensland. The role of these teachers is to support implementation of a robust primary school science curriculum aligned with current Education Queensland priorities, with a focus on supporting Years 4–7 teachers in planning, teaching, resource management, curriculum links, assessment, establishing professional learning communities and leadership. They also support students as they actively engage in inquiry-based learning.

Regional monthly reports indicate that positive changes have already occurred in schools through collaborative development of school science programs, lesson modelling, science resource audits and assistance with running hands-on activities for students. These new skills will help build a community with a high level of scientific literacy and a supply of trained specialists in science and technology

Earth Smart Science program

During its 2009 election campaign, the Queensland Government committed $5.8 million over three years to expand the number of environmentally sustainable Earth Smart Science (ESS) schools from 60 to 1000 and declared 2010 as the Year of Environmental Sustainability in Schools.

Earth Smart Science schools will:

- work to reduce their ecological footprint through the development and implementation of School Environment Management Plans (SEMPs)
- focus on waste minimisation, water conservation, energy efficiency and biodiversity improvements
- work with QESSI hubs who will assist the schools to develop their School Environment Management Plan (SEMP) and begin (or continue) their journey becoming an “Earth Smart School”.

The Earth Smart Science program will:

- foster knowledge of and commitment to environmental sustainability within Queensland state primary schools through a whole-of-school approach
- reduce the ecological footprint of state primary schools across Queensland
- have 1000 Queensland state primary schools in the ESS program, including P–10 and P–12 by 2012. High schools, special and non-state schools are not targeted through this program.

School targets

Completion and implementation of their SEMP Biodiversity improvements

By 2012 schools aim to reduce:

- overall school water consumption by 15%
- overall school energy consumption by 30%
- overall school waste consumption by 50%.

School inputs

As part of the Earth Smart Science program schools receive:

- three days TRS for SEMP planning, PD and support
- assistance in building community links
- opportunities to work with leaders in the field
- assistance by QESSI hubs to link with partners to enrich learning
- the chance to make a difference for the future.

The Earth Smart Science program will link with other Education Queensland environmental sustainability initiatives, including the $60 million Solar and Energy Efficiency in Schools program, the Science Spark program and the Year of Environmental Sustainability in 2010.

Queensland Catholic Education Commission

Catholic schooling authorities have identified science as an area for targeted professional development and support in 2010 and beyond, especially in view of impending changes brought about by the implementation of the Australian curriculum and the transition of Year 7 into secondary school. Each Catholic schooling authority has targeted professional development provision and support according to the needs and context of their schools, but some common approaches are evident:

- *Primary Connections* has been a major focus for school programs and PD with several schooling authorities.
- Schooling authorities have trained facilitators to work with school curriculum coordinators in conducting science professional development for all staff and mentoring/modeling to individual teachers.
- Additional curriculum officers, with a focus on science, are being employed by schooling authorities to facilitate science professional development.
- Additional funding has been allocated by one Catholic schooling authority to enable purchase of science resources and materials to support quality teaching of science in primary school.
- Science KLA (expert) panels have been formed to assist development of quality school-based science programs and ensure educational content and authentic scientific approaches to science. The Science KLA Panels are also available for schools to use in a mentoring role with all staff or individual staff member meetings.
- Science experts with involvement in Australian Curriculum science development have been used, providing professional development for curriculum personnel and modelling for teachers in teaching science.
- The Consistency of Teacher Judgment (CTJ) process has focused on Science and science inquiry over the last two years, and will continue in 2011 based on the Australian Curriculum Science.
- Contract with QUT to conduct a longitudinal research project into science teaching in our primary schools. Phase 1 of the research has been completed and the report is being prepared. Phase 2 will commence in 18 months.

Appendix 3

Interpreting 95% confidence intervals

Whenever statistics are reported, generally the figure that is reported is also associated with either an "error" or a "95% confidence interval". Both of these figures are designed to show an estimate of how "accurately" we know the figure that is being reported. The interpretation of confidence intervals and errors is generally poorly understood. In the context of this report, figures are reported with 95% confidence intervals, so this section is restricted to interpretation of these.

A 95% confidence interval generally represents the upper and lower ranges within which, statistically, we would have a 95% certainty that the "true" value would lie. This gives rise to a number of misunderstandings about the reported interval. The first interpretation that is often placed on the confidence interval is that, statistically, the "true" value is equally likely to lie anywhere within the 95% interval. In fact, the most probable position of the true value is where the statistic (such as the mean) is reported, and the probability of it being further away from this becomes lower the further towards the edge of the confidence interval one goes.

This often leads to another interpretation, which is that if two confidence intervals overlap, there is "no statistical difference" between the two reported statistics. In fact, if two confidence intervals marginally overlap, the probability of one lying below the 95% confidence interval is 5%, or 1 in 20. Similarly, the probability of the other lying above the 95% confidence interval is also 1 in 20. This means that if two confidence intervals marginally overlap the probability that the two statistics are in fact in the reverse rank order to that which is reported is less than 1 in 400. In fact, because of the nature of statistics, the probability is actually far less than that.

It should be noted, however, that the confidence interval is a purely statistical construct, and does not necessarily represent all sources of uncertainty. There are unknown sources of uncertainty that cannot be represented in the reported error. These are often things associated with whether or not the test is really testing what it is suggested that it should be, or balance within test items in terms of types of items and content coverage. These things cannot be precisely statistically measured. A well-constructed spelling test might perform well statistically on the surface as a science test, but it will still not be testing science.

Queensland Studies Authority
154 Melbourne Street, South Brisbane
PO Box 307 Spring Hill
QLD 4004 Australia
T +61 7 3864 0299
F +61 7 3221 2553
www.qsa.qld.edu.au