Programme for International Student Assessment

A teacher's guide to PISA scientific literacy

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1

Introduction

The Programme for International Student Assessment (PISA) is an international assessment of the skills and knowledge of 15-year olds. A project of member countries of the Organisation for Economic Co-operation and Development (OECD), it has taken place at three year intervals since 2000. Detailed reports of Australian students' performance and their attitudes and beliefs towards science in PISA can be found in the full reports written to inform the wider educational community. In December 2013 the results of the most recent PISA assessment, PISA 2012, will be released.

The full national reports can be found, along with much more information about PISA, at www.acer.edu.au/ozpisa.

After each three-year cycle, a number of items from the assessment are released by the OECD so that educators are able to see how the assessment is constructed. By combining these released items with a description of Australian students' performance on the items, and providing an overall picture of achievement in the subject area, this report (and the companion reports on mathematical literacy and reading literacy) aims to enable teachers to gain a deeper understanding of PISA and to use the results of the assessment to inform their teaching.

More and more, policy makers are using the results of studies such as PISA to make decisions about education – for example the Australian Government's *National Plan for School Improvement* establishes a new target to place Australia in the top five countries in the world in reading, numeracy and science by 2025 (see www.betterschools.gov.au). It is important that practitioners and others understand the assessments which underpin the goals, and think about how they are able to make a difference to the outcomes of Australian children.

The aim of this report is to provide this understanding, and encourage discussion about assessment, achievement and benchmarking within the wider educational community.

PISA … what is it?

PISA is a key part of Australia's National Assessment Program (NAP). Alongside NAPLAN, which is a census of students at Years 3, 5, 7 and 9, nationally representative samples of students participate in three national assessments in science literacy, civics and citizenship, and ICT literacy. Together with these, nationally representative samples of Australian students also participate in two international studies as part of the NAP (Figure 1.1). These studies enable Australia to benchmark our students in reading, mathematical and scientific literacy against similar samples of students in more than 60 other countries.

PISA is a key part of the MCEECDYA National Assessment Program

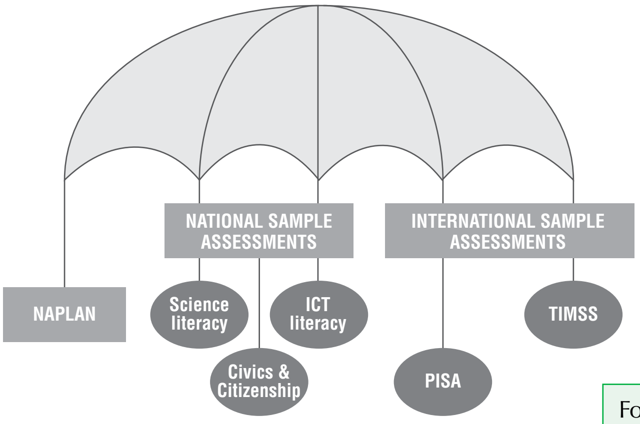

Figure 1.1 Components of the National Assessment Program

For more details about the NAP, see–www.nap.edu.au

PISA was designed to assist governments in monitoring the outcomes of education systems in terms of student achievement on a regular basis and within an internationally accepted common framework, in other words, to allow them to compare how students in their countries were performing on a set of common tasks compared to students in other countries. In this way, PISA helps governments to not only understand, but also to enhance, the effectiveness of their educational systems and to learn from other countries' practices.

Students aged 15 were chosen as the target group in PISA as compulsory schooling ends at this age in many countries.

PISA seeks to measure how well young adults, at age 15 and therefore near the end of compulsory schooling in most participating education systems, have acquired and are able to use knowledge and skills in particular areas to meet real-life challenges.

In addition to assessing facts and knowledge, PISA assesses students' ability to use their knowledge to solve real-world problems. Thus, the term 'literacy' is used, since it implies not only knowledge of a domain, but also the ability to apply that knowledge.

As part of PISA, students complete an assessment including items testing reading literacy, mathematical literacy and scientific literacy. In each cycle of PISA, one of the cognitive areas is the main focus of the assessment, with most of the items focussing on this area and fewer items on the other two areas (although still enough items to provide links between years) (see Figure 1.2 – shading indicates the major domain of the cycle). Students also complete an extensive background questionnaire, and school principals complete a survey describing the context of education at their school, including the level of resources in the school, qualifications of staff and teacher morale.

PISA 2000	PISA 2003	PISA 2006	PISA 2009	PISA 2012
Reading Literacy	Reading Literacy	Reading Literacy	Reading Literacy	Reading Literacy
Mathematical Literacy	Mathematical Literacy	Mathematical Literacy	Mathematical Literacy	Mathematical Literacy
Scientific Literacy	Scientific Literacy	Scientific Literacy	Scientific Literacy	Scientific Literacy

Figure 1.2 Cycles of PISA and the major and minor domains of assessment for each cycle

The reporting of the findings from PISA focuses on issues such as:

- How well are young adults prepared to meet the challenges of the future?
- Can they analyse, reason and communicate their ideas effectively?
- What skills do they possess that will facilitate their capacity to adapt to rapid societal change?
- Are some ways of organising schools or school learning more effective than others?
- What influence does the quality of school resources have on student outcomes?
- What educational structures and practices maximise the opportunities of students from disadvantaged backgrounds?
- How equitable is the provision of education within a country or across countries?

What do PISA students and schools do?

Cognitive assessment

Students completed a pen-and-paper assessment and a context questionnaire

In PISA 2009, the majority of the assessment was devoted to reading literacy, with mathematical literacy and scientific literacy assessed to a lesser extent. Participating students each completed a two-hour paper-and-pen assessment.

A sub-sample of students who participated in the paper-and-pen assessment also completed an assessment of digital reading literacy, which used the information technology infrastructure (computer laboratories) at schools.

The item data for this report are based on PISA 2006, as scientific literacy was the major focus in that cycle.

Context questionnaire

The data collected in the 35-minute Student Questionnaire provide an opportunity to investigate factors that may influence performance and consequently give context to the achievement scores. Responses to a set of 'core' questions about the student and their family background, (including age, year level and socioeconomic status) are collected during each assessment. In 2006, students were also asked about their attitudes, engagement and motivation in science.

Information at the school-level was collected through a 30-minute online School Questionnaire, answered by the principal (or the principal's designate). The questionnaire sought descriptive information about the school and information about instructional practices.

Students completed a background survey and principals a school survey. The survey results provide rich context for the achievement data.

Participants in PISA 2009

Although PISA was originally created by OECD governments, it has become a major assessment tool in many regions and countries around the world. Since the first PISA assessment in 2000, the number of countries or economic regions who have participated from one PISA cycle to the next has increased. Sixty-five countries participated in PISA 2009, comprising 34 OECD countries and 31 partner countries/economies (Figure 1.2).

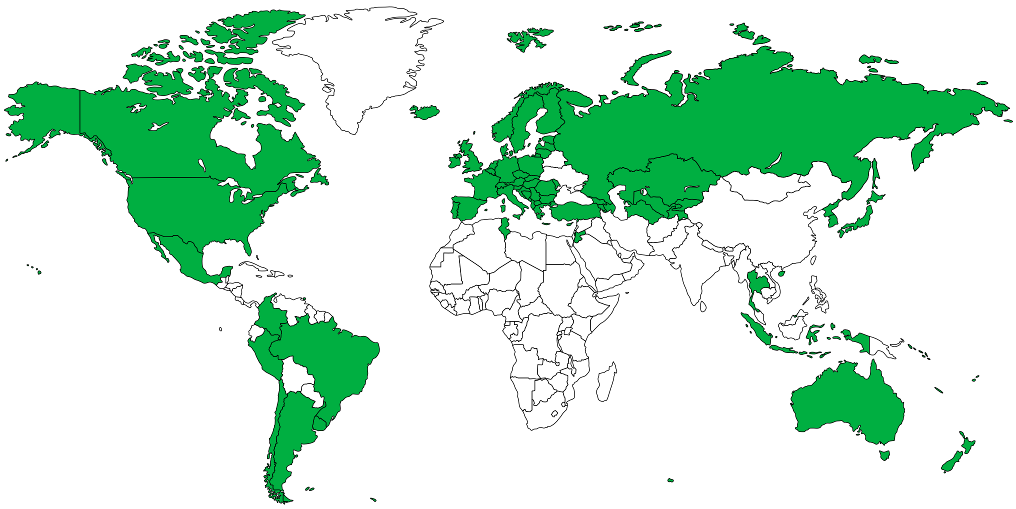

Figure 1.2 Countries participating in PISA 2009

OECD countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America.

Partner countries/economies: Albania, Argentina, Azerbaijan, Brazil, Bulgaria, Chinese Taipei, Colombia, Croatia, Dubai (UAE), Hong Kong-China, Indonesia, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Macao-China, Montenegro, Panama, Peru, Qatar, Romania, Russian Federation, Serbia, Shanghai-China, Singapore, Thailand, Trinidad and Tobago, Tunisia, Uruguay.

Schools and students

It's important that a range of schools is selected and that a range of students is selected from within schools. This way we are able to get an accurate picture of the whole Australian student population.

The target population for PISA is students who are 15 years old and enrolled at an educational institution, either full- or part-time, at the time of testing. In most countries, 150 schools and 35 students in each school were randomly selected to participate in PISA. In some countries, including Australia, a larger sample of schools and students participated. The Australian sample for PISA 2009 consisted of 353 schools and 14,251 students. In Australia's case, a larger sample provides the ability to report reliable results for each state and territory and for Indigenous students. The larger PISA sample is also used as the next cohort for the Longitudinal Survey of Australian Youth (LSAY). The Australian sample for PISA 2009 consisted of 353 schools and 14,251 students. The Australian sample for PISA 2006 consisted of 356 schools and 14,170 students.

This report

This report is one of a series of three reports that focus on Australian students' performance on the PISA items that have been released in each of the assessment domains: reading literacy, mathematical literacy and scientific literacy. Further information about PISA in Australia is available from the national PISA website - www.acer.edu.au/ozpisa while further details about Australia's participation and performance in PISA 2009 is available in Challenges for Australian Education: Results from PISA 2009.

This report focuses on scientific literacy. Chapter 2 of this report provides a brief overview of the PISA Scientific Literacy Framework, so that educators gain an understanding of the context in which the questions for the assessment are written, and an overview of Australia's results in the PISA 2006 international assessment. Chapter 3 provides all of the released items in science for PISA, along with marking guides, examples of responses and the performance of Australian students and that of students in comparison countries on these items. The focus of Chapter 4 is the context behind achievement: attitudes and beliefs, engagement and motivation, and recognition of environmental issues.

Chapter

2

Scientific literacy in PISA

How is scientific literacy defined in PISA?

An understanding of science and technology is central to a young person's preparedness for life in modern society, in which science and technology play a significant role. This understanding also empowers individuals to participate appropriately in understanding public policy where issues of science and technology impact on their lives, and contributes significantly to the personal, social, professional and cultural lives of everyone.

The PISA scientific literacy domain refers to an individuals':

> … scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, to explain scientific phenomena and to draw evidence-based conclusions about science related issues; their understanding of the characteristic features of science as a form of human knowledge and enquiry; their awareness of how science and technology shape our material, intellectual and cultural environments; and their willingness to engage with science-related issues, and with the ideas of science, as a reflective citizen.

The definition includes knowledge of science, which refers to the knowledge of the natural world across the major fields of physics, chemistry, biological science, Earth and space science, and science-based technology, and knowledge about science, which refers to the knowledge of the means (scientific enquiry) and the goals (scientific explanations) of science.

How is scientific literacy measured in PISA?

The scientific literacy framework comprises four interrelated aspects: the contexts in which tasks are embedded, the competencies that students need to apply, the knowledge domains involved, and students´ attitudes towards science. These are shown in Figure 2.1.

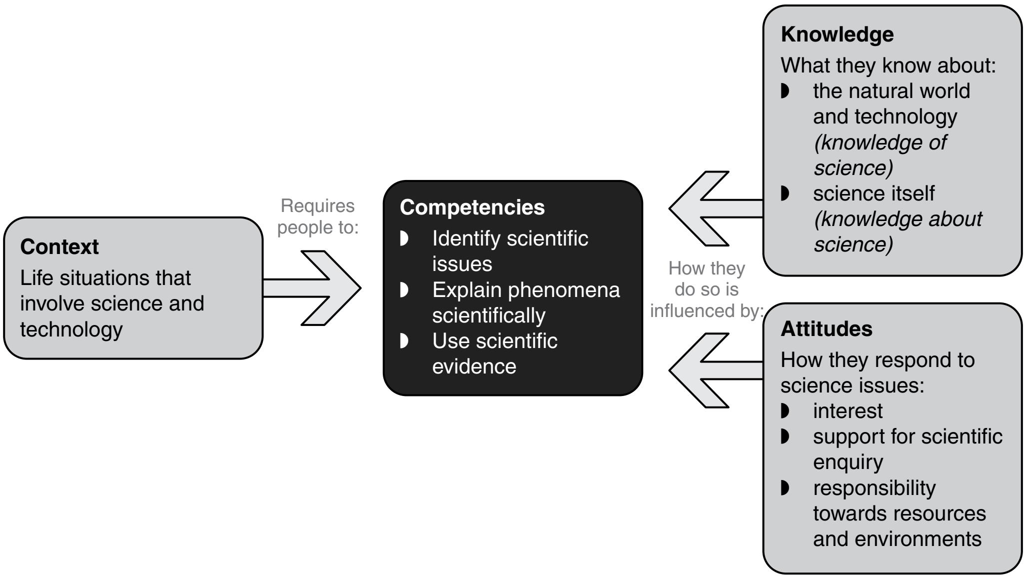

Figure 2.1 The components of the PISA scientific literacy framework[1]

Situations and context

PISA´s orientation focuses on preparing students for their future lives, and so the items for the PISA science assessment are situated in general life, not just life in the classroom. In the PISA scientific literacy assessment, the focus of the items is on situations relating to the self, family and peer groups (*personal*), to the community (*social*) and to life across the world (*global*). Some items are framed in an historical situation, in which an understanding of the advances in scientific knowledge can be assessed.

The context of an item is its specific setting within a situation. It includes all of the detailed elements used to formulate the question.

Figure 2.2 lists the applications of science, within *personal, social* and *global* situations, which are primarily used as the contexts for the PISA assessment. These are not definitive: other situations, such as *technical* and *historical*, and areas of application are also used in PISA. The applications were drawn from a wide variety of life situations and were generally consistent with the areas of application for scientific literacy in the PISA 2000 and 2003 frameworks, prior to PISA 2006 when scientific literacy was the major domain. The areas of application are: *health*, *natural resources*, *the environment*, *hazards* and *the frontiers of science and technology*. These are the areas in which scientific literacy has particular value for individuals and communities in enhancing and sustaining quality of life, and in the development of public policy.

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[1] Source: OECD. (2006). *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006*. Paris: OECD (Figure 1.1, p.26).

	Personal (self, family and peer groups)	**Social (the community)**	**Global (life across the world)**
Health	maintenance of health, accidents, nutrition	control of disease, social transmission, food choices, community health	epidemics, spread of infectious diseases
Natural resources	personal consumption of materials and energy	maintenance of human populations, quality of life, security, production and distribution of food, energy supply	renewable and non-renewable energy sources, natural systems, population growth, sustainable uses of species
Environment	environmentally friendly behaviour, use and disposal of materials	population distribution, disposal of waste, environmental impact, local weather	biodiversity, ecological sustainability, control of pollution, production and loss of soil
Hazard	natural and human-induced decisions about housing	rapid changes (earthquakes, severe weather), slow and progressive changes (coastal erosion, sedimentation), risk assessment	climate change, impact of modern warfare
Frontiers for science and technology	interest in science's explanations of natural phenomena, science-based hobbies, sport and leisure, music and personal technology	new materials, devices and processes, genetic modification, weapons technology, transport	extinction of species, exploration of space, origin and structure of the universe

Figure 2.2 Contexts for the PISA scientific literacy assessment

Scientific competencies

The PISA scientific literacy assessment items required students to identify scientifically oriented issues, explain phenomena scientifically, and use scientific evidence. These three competencies were chosen because of their importance to the practice of science and their connection to key cognitive abilities such as inductive and deductive reasoning, systems-based thinking, critical decision-making, transformation of information (e.g. creating tables or graphs out of raw data), and thinking in terms of models and use of science. The essential features of each of the three competencies are described and elaborated in Figure 2.3.

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

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

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

Figure 2.3 PISA scientific competencies

Scientific issues must lend themselves to answers based on scientific evidence. The competency *identifying scientific issues* includes recognising questions that it would be possible to investigate scientifically in a given situation and identifying keywords to search for scientific information on a given topic. It also involves recognising key features of a scientific investigation; for example, what things should be compared, what variables should be changed or controlled, what additional information is needed, or what action should be taken so that relevant data can be collected. *Identifying scientific issues* requires students to possess knowledge about science itself, and may also draw on students´ knowledge of science.

Students demonstrate *explaining phenomena scientifically* by applying appropriate knowledge of science in a given situation. The competency includes describing or interpreting phenomena and predicting changes, and may involve recognising or identifying appropriate descriptions, explanations, and predictions.

The competency *using scientific evidence* requires students to make sense of scientific findings as evidence for claims or conclusions. The required response can involve knowledge about science or knowledge of science or both. Students should be able to assess scientific information and produce arguments based on scientific evidence. The competency may also involve: selecting from alternative conclusions in relation to evidence, giving reasons for or against a given conclusion in terms of the process by which the conclusion was derived from the data provided, and identifying the assumptions made in reaching a conclusion. Reflecting on the societal implications of scientific or technological developments is another perspective of this competency.

Scientific knowledge

As noted previously, scientific knowledge refers to both *knowledge of science* (knowledge about the natural world) and *knowledge about science* itself.

Knowledge of science

Clearly only a sample of students´ knowledge of science could be assessed in any one PISA assessment, and the focus of the assessment is the extent to which students are able to apply their knowledge in contexts of relevance to their lives. The assessed knowledge was selected from the major fields of physics, chemistry, biology, Earth and space science, and technology according to the following criteria. Items had to be:

- relevant to real-life situations scientific knowledge differs in the degree to which it is useful to the life of individuals;
- representative of important scientific concepts and thus have enduring utility; and
- appropriate to the developmental level of 15-year-old students.

Figure 2.4 shows the four content areas defined within *knowledge of science*. The four areas represent knowledge required for understanding the natural world and for making sense of experiences in *personal, social* and *global* contexts. For this reason the framework uses the term “systems” instead of “sciences” in the descriptors of the content areas. The intention is to convey the idea that citizens have to understand concepts from the physical and life sciences, Earth and space science, and technology in different contexts.

Physical systems

- Structure of matter (e.g. particle models, bonds)
- Properties of matter (e.g. changes of state, thermal and electrical conductivity)
- Chemical changes of matter (e.g. reactions, energy transfer, acids/bases)
- Motions and forces (e.g. velocity, friction)
- Energy and its transformation (e.g. conservation, dissipation, chemical reactions)
- Interactions of energy and matter (e.g. light and radio waves, sound and seismic waves)

Living systems

- Cells (e.g. structures and functions, DNA, plant and animal)
- Humans (e.g. health, nutrition, subsystems [i.e. digestion, respiration, circulation, excretion, and their relationship], disease, reproduction)
- Populations (e.g. species, evolution, biodiversity, genetic variation)
- Ecosystems (e.g. food chains, matter and energy flow)
- Biosphere (e.g. ecosystem services, sustainability)

Earth and space systems

- Structures of Earth systems (e.g. lithosphere, atmosphere, hydrosphere)
- Energy in Earth systems (e.g. sources, global climate)
- Change in Earth systems (e.g. plate tectonics, geochemical cycles, constructive and destructive forces)
- Earth's history (e.g. fossils, origin and evolution)
- Earth in space (e.g. gravity, solar systems)

Technology systems

- Role of science-based technology (e.g. solve problems, help humans meet needs and wants, design and conduct investigations)
- Relationships between science and technology (e.g. technologies contribute to scientific advancement)
- Concepts (e.g. optimisation, trade-offs, cost, risk, benefit)
- Important principles (e.g. criteria, constraints, innovation, invention, problem solving)

Figure 2.4 PISA categories of ***knowledge of science***

Knowledge about science

As well as *knowledge of science*, PISA assesses *knowledge about science*, for which the framework for scientific literacy defines two categories. The first of these is “scientific enquiry”, which centres on enquiry as the central process of science and the various components of that process. The second is “scientific explanations”, which are the result of scientific enquiry. Enquiry can be thought of as the means of science – how scientists obtain evidence – and explanations as the goals of science – how scientists use data. The examples shown in Figure 2.5 convey the general meanings of the two categories.

Scientific enquiry

- Origin (e.g. curiosity, scientific questions)
- Purpose (e.g. to produce evidence that helps answer scientific questions, current ideas/ models/theories guide enquiries)
- Experiments (e.g. different questions suggest different scientific investigations, design)
- Data (e.g. quantitative [measurements], qualitative [observations])
- Measurement (e.g. inherent uncertainty, replicability, variation, accuracy/precision in equipment and procedures)
- Characteristics of results (e.g. empirical, tentative, testable, falsifiable, self-correcting)

Scientific explanations

- Types (e.g. hypothesis, theory, model, scientific law)
- Formation (e.g. existing knowledge and new evidence, creativity and imagination, logic)
- Rules (e.g. logically consistent, based on evidence, based on historical and current knowledge)
- Outcomes (e.g. new knowledge, new methods, new technologies, new investigations)

Figure 2.5 PISA categories of ***knowledge about science***

The structure of the assessment

Item response formats

Similar to the item formats for reading literacy and mathematical literacy, students were presented with units that required them to construct a response to a stimulus and a series of questions (or “items”). Context was represented in each unit by the stimulus material, which was typically a brief written passage or text accompanying a table, chart, graph, photograph or diagram, and then each unit contained several questions or items. While students needed to possess a certain level of reading competency in order to understand and answer the science items, the stimulus material used language that was as clear, simple and brief as possible while still conveying the appropriate meaning. More importantly, the items required students to use one or more of the scientific competencies as well as knowledge of science and/or knowledge about science.

The scientific literacy units in PISA 2009 incorporated up to four cognitive items that assessed students’ scientific competencies. Each item involved the predominant use of the skills involved in one of the scientific competencies, and primarily required knowledge of science or knowledge about science. In most cases, more than one competency and more than one knowledge category were assessed (by different items) in this way within a unit.

Distribution of items

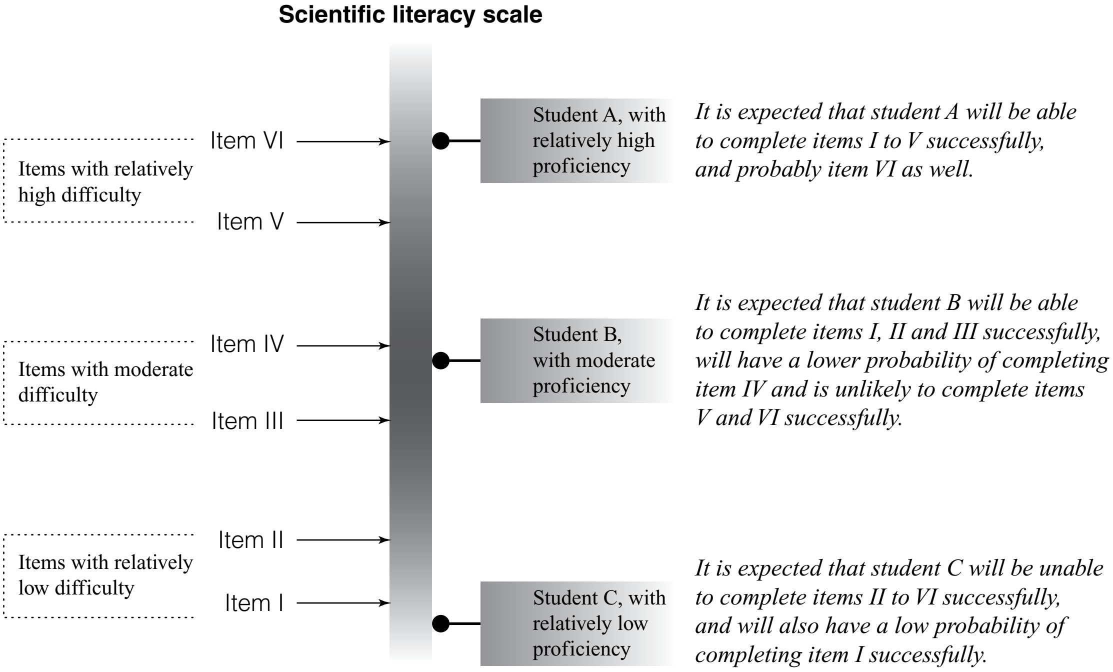
Five types of items were used to assess the competencies and scientific knowledge identified in the framework: multiple-choice items, complex multiple-choice items, closed constructed-response items, short response items and open constructed-response items. The PISA 2009 assessment consisted of 18 science units (53 items). Almost half of the items were multiple-choice items or complex multiple-choice items. Another third of the items either required closed constructed responses or short responses. The remaining fifth of the items were open constructed-response items that require a relatively extended written or drawn response from students.

Detailed information about the construction of assessment booklets and the marking of PISA items can be found in the national report, available from www.acer.edu.au/ozpisa.

Scaling the scientific literacy tasks

The scale of scientific literacy was constructed using Item Response Theory, with scientific literacy items ranked by difficulty and linked to student proficiency. Using such methods means that the relative ability of students taking a particular test can be estimated by considering the proportion of test items they answer correctly, while the relative difficulty of items in a test can be estimated by considering the proportion of students getting each item correct. On this scale, it is possible to estimate the location of individual students, and to describe the degree of scientific literacy that they possess.

The relationship between items and students on the scientific literacy scale (shown in Figure 2.6) is probabilistic. The estimate of student proficiency reflects the kinds of tasks they would be expected to successfully complete. A student whose ability places them at a certain point on the PISA scientific literacy scale would most likely be able to successfully complete tasks at or below that location, and increasingly more likely to complete tasks located at progressively lower points on the scale, but would be less likely to be able to complete tasks above that point, and increasingly less likely to complete tasks located at progressively higher points on the scale.



It is expected that student A will be able to complete items I to V successfully, and probably item VI as well.

It is expected that student B will be able to complete items I, II and III successfully, will have a lower probability of completing item IV and is unlikely to complete items V and VI successfully.

It is expected that student C will be unable to complete items II to VI successfully, and will also have a low probability of completing item I successfully.

Figure 2.6 The relationship between items and students on the scientific literacy scale

Reporting scientific literacy performance: mean scores and proficiency levels

The results for all countries for PISA 2000 – 2009 are available through the international and national reports (www.acer.edu.au/ozpisa). The following section of this report will provide a brief overview of Australia's results compared to those of some other countries, and will give the reader an idea of how Australian students perform on this assessment compared to:

- other native English speaking countries (Canada, New Zealand, United States);
- Finland (highest scoring country previously);
- high-achieving Asian neighbours (Hong Kong – China, Korea, Shanghai – China, Singapore); and
- the OECD average.

Mean scores and distribution of scores

Student performance in PISA is reported in terms of statistics such as mean scores and measures of distributions of achievement, which allow for comparisons against other countries and subgroups. Mean scores provide a summary of student performance and allow comparisons of the relative standing between different student subgroups. In PISA 2006, the mean score for scientific literacy across participating OECD countries was set at 500 score points with a standard deviation of 100, and in PISA 2009 the OECD average was 501 score points.[2] This mean score is the benchmark against which future performance in scientific literacy in PISA is compared.

Figure 2.7 shows the PISA 2009 scores of the countries listed below in scientific literacy relative to the OECD average. All countries that are annotated with an asterisk (*) scored at a level significantly higher than the OECD average of 501, and the countries whose bars are shaded in dark green are those whose scores were significantly higher than those of Australia.

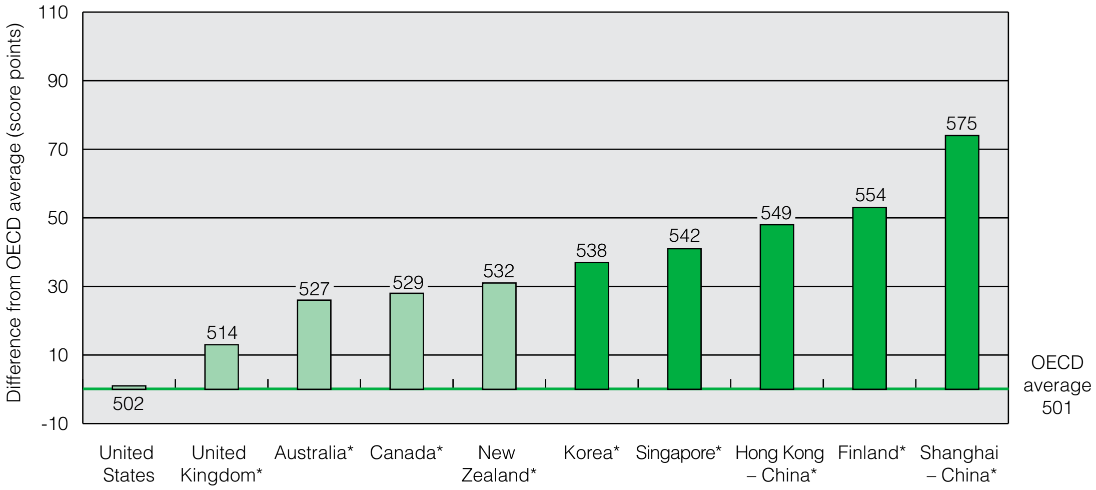


Figure 2.7 PISA 2009 scientific literacy achievement comparison with OECD average score

There were statistically significant gender differences in scientific literacy performance in many participating countries, with gender differences in favour of males in a number of countries including Germany, the United States and the United Kingdom, and in favour of females in as

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[2] The OECD average reflects the mean score for all OECD countries. The OECD average can change from each PISA assessment because the number of participating countries differs (for eg. in 2006, there were 30 OECD countries and in 2009 this had increased to 34 OECD countries) and also because the overall performance for a country can change.

many countries, including Poland, Greece, Turkey and Finland. There was no significant difference in the average performance of females and males in Australia.

Interpreting such data can be challenging. We know what the mean and standard deviation are, but what does this mean in practical terms? Fortunately we are able to get a rough measure of how many score points comprise a year of schooling, given that 15-year-old students are often in adjacent grades.

For Australia, in scientific literacy, one year of schooling was found to be the equivalent of 37 score points.

Looking at the difference between the scores of students in Shanghai – China and those in Australia, the score difference of 48 score points translates to about 15 months of schooling.

Proficiency levels

While mean scores provide a comparison of student performance on a numerical level, proficiency levels provide a description of the knowledge and skills that students are typically capable of displaying. This produces a picture of the distribution of student performance within a country (or other groups of students) across the various proficiency levels. In PISA 2006, six levels of proficiency for scientific literacy were defined, which have remained unchanged for subsequent cycles. The continuum of increasing scientific literacy (with Level 6 as the highest and Level 1 as the lowest proficiency level) is shown in Figure 2.8, along with the summary descriptions of the kinds of scientific competencies associated with the different levels of proficiency. A difference of 62 score points represents one proficiency level on the PISA scientific literacy scale.

	Students at this level can…
☐ Level 6	identify, explain and apply scientific knowledge in a variety of complex life situations; link information sources and explanations and use evidence from those sources to justify decisions; clearly and consistently demonstrate advanced scientific thinking and reasoning; use their scientific understanding in support of solutions to unfamiliar scientific and technological situations.
🟩 Level 5	identify the scientific components of many complex life situations; apply both scientific concepts and knowledge about science to these situations; use well-developed inquiry abilities; link knowledge appropriately and bring critical insights to situations; construct explanations based on evidence and arguments.
🟩 Level 4	work effectively with situations and issues that may involve explicit phenomena; integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations; reflect on actions and communicate decisions using scientific knowledge and evidence.
🟩 Level 3	identify clearly described scientific issues in a range of contexts; select facts and knowledge to explain phenomena and apply simple models or inquiry strategies; interpret and use scientific concepts from different disciplines and apply them directly.
🟩 Level 2	use adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations.
⬛ Level 1	present scientific explanations that are obvious and follow explicitly from given evidence; scientific knowledge is limited to a few, familiar situations.
⬛ Below Level 1	not demonstrate even the most basic types of scientific literacy that PISA measures. These students are likely to be seriously disadvantaged in their lives beyond school.

Figure 2.8 Summary descriptions of the six proficiency levels on the overall scientific literacy scale

Students who scored below 335 score points are placed below Level 1. This is not to say that these students were incapable of performing any scientific tasks, but they were unable to utilise scientific skills in a given situation as required by the easiest PISA tasks. Their pattern of answers was such that they would be expected to be able to solve fewer than half of the tasks in a test made up solely of questions drawn from Level 1.

Internationally, Level 2 has been defined as a ‘baseline’ proficiency level as it represents a standard level of scientific literacy proficiency where students begin to demonstrate the kind of skills that enable them to actively use science as stipulated by the PISA definition.

The percentage of students at each of the proficiency levels is shown in Figure 2.9. Clearly, Australia is doing reasonably well in scientific literacy, with just 12 per cent not achieving the lowest levels described by MCEECDYA as being an acceptable standard.

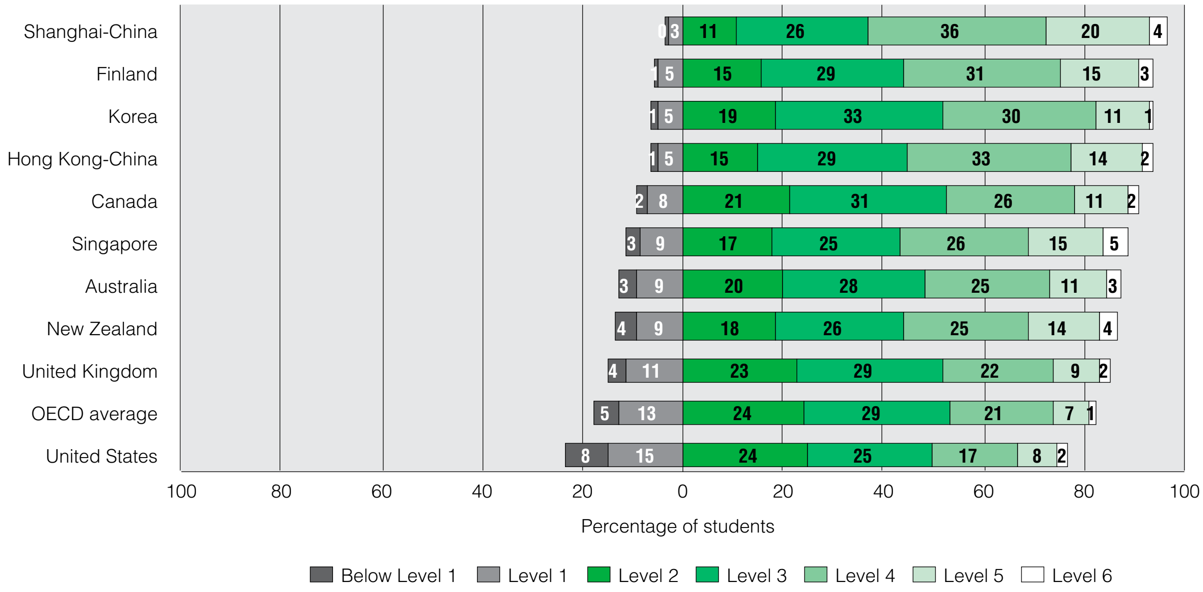

Figure 2.9 PISA 2009 proportions of students at scientific proficiency levels for Australia and comparison countries

However it is also evident from the figure that Australia has a higher proportion of students in the lower scientific literacy levels than some other countries and a lower proportion of students in the higher levels of achievement. Both need to be addressed if Australia’s achievement is to improve.

Gender differences

The proportions of females and males at each of the scientific literacy proficiency levels in Australia and across the OECD countries are shown in Figure 2.10.

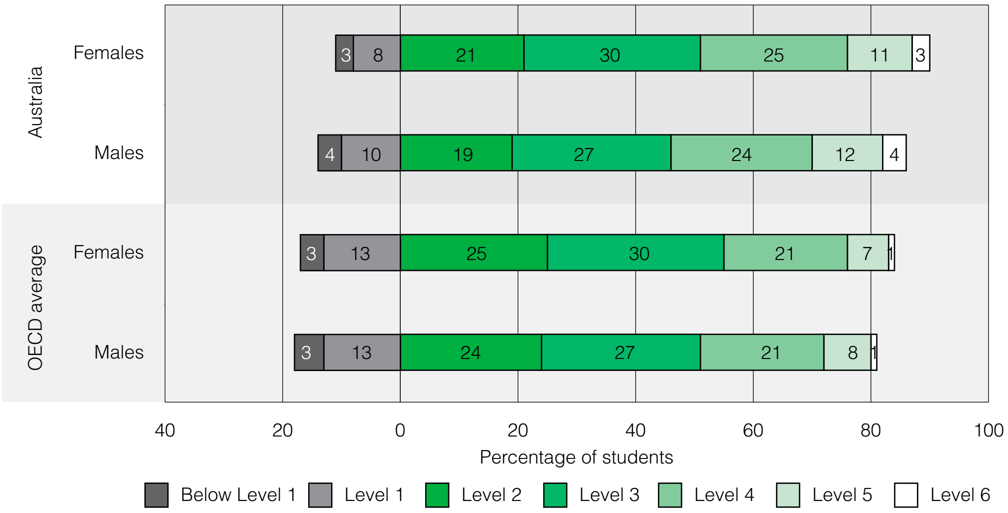

Figure 2.10 PISA 2009 proportions of students at scientific proficiency levels by gender, Australia and OECD average

- A slightly larger proportion of male than female students in Australia achieved at the higher proficiency levels, however a slightly larger proportion of males than females also failed to achieve proficiency level 2.
- In Australia, 14 per cent of females and 16 per cent of males reached Level 5 or 6, compared to 8 per cent of females and 9 per cent of males across OECD countries.

Performance on the PISA knowledge domains

There were two knowledge domains defined in scientific literacy – knowledge about science and knowledge of science. Australian students scored significantly higher than the OECD average in both domains. The domain *knowledge of science* is divided into four content areas: physical systems, living systems, Earth and space systems, and technology systems. Technology systems was not reported in PISA 2006 as there were too few items to do so accurately. The difference between Australian male and female students' scores and the OECD average on each of the three reportable content areas is shown in Figure 2.11.

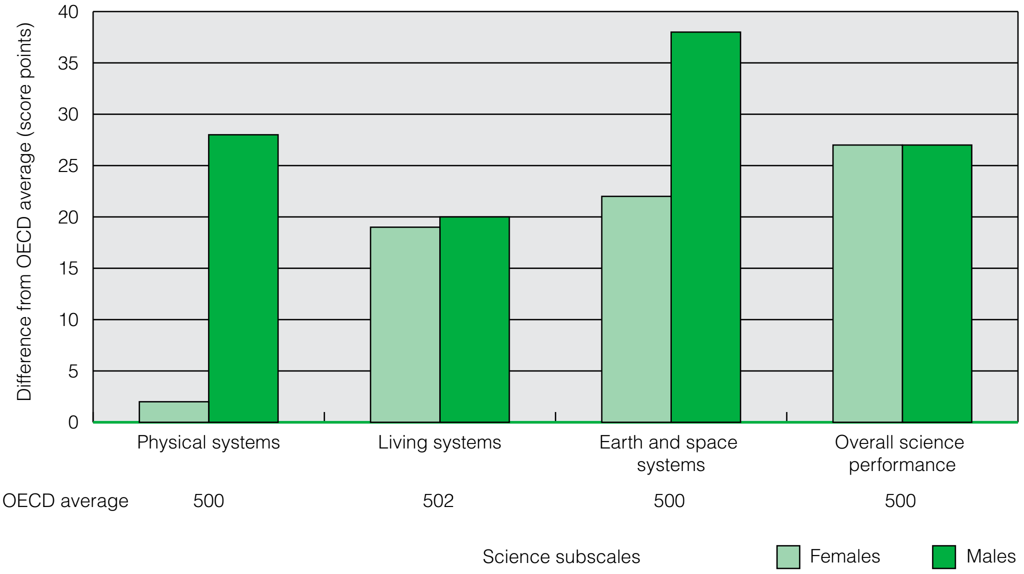

Figure 2.11 PISA 2006 performance on science content areas for Australian students relative to OECD average

- Overall, Australian students scored significantly better than the OECD average on each of the subscales.
- The largest gender differences are apparent in *physical systems* and *Earth and space systems*, in which males scored substantially as well as significantly higher than females.
- Australian students performed relatively best on *Earth and space systems*.
- Female Australian students performed relatively poorly compared to male Australian students in *physical systems*, achieving a score not significantly different to the OECD average.

Are there particular ways that subjects such as physics could be taught to improve the results of female students relative to male students?

Performance over time

One of the main aims of PISA is to examine student performance over time so that policy makers can monitor learning outcomes in both a national and international context. PISA 2006 defined the scientific literacy framework in detail, and so comparisons can be made with this point in time.

A handful of countries saw an improvement in their science literacy scores from 2006 to 2009, but Australia's average score remained the same. As has been discussed in the main Australian PISA report, scores in mathematical literacy and reading literacy have declined over cycles, but the scores for science have not, and the proportion of students achieving both the highest and lowest levels has remained the same.

Results for other groups of students within Australia

Indigenous students:

- achieved a mean score of 449 points, compared to a mean score of 530 points for non-Indigenous students. The difference in scores is the equivalent of more than two years of schooling.
- were underrepresented at the higher end of the scientific literacy proficiency scale. Less than three per cent achieved at or above Level 5, compared to 15 per cent of non-indigenous Australian students and an average of eight per cent of students across the OECD.
- were over-represented at the lower end of the scientific literacy proficiency scale. Thirty-five per cent failed to reach Level 2, compared to 18 per cent of students across the OECD and 12 per cent of non-Indigenous students in Australia.

Students with a language background other than English:

- performed, on average, at a significantly higher level than students who spoke English as their main language, with mean scores of 532 and 512 points respectively. Similar proportions of students with a language background other than English and students who spoke English at home achieved at or above Level 5 (14% and 15% respectively).
- were more likely than students with an English speaking background to not reach Level 2, (19% and 11% respectively).

Students from the lowest quartile of socioeconomic background:

- achieved a mean score of 481 points compared to students in the highest quartile who achieved a mean score of 577 points.
- were overrepresented at the lower levels of achievement and underrepresented at the higher levels. Just six per cent of students in the lowest quartile compared with 28 per cent of students in the highest quartile achieved at or above Level 5, while four per cent of students in the highest quartile of socioeconomic background, compared to 22 per cent of students in the lowest quartile failed to reach Level 2.

This difference was equivalent to almost three full years of schooling

Students in metropolitan areas:

- performed at a significantly higher level than students in schools from provincial areas, who in turn performed at a significantly higher level than students attending schools in remote areas.
- were more likely to achieve at the higher proficiency levels - 15 per cent from metropolitan schools, 11 per cent from provincial schools and six per cent of students from remote schools achieved at or above Level 5.
- were less likely to achieve at the lower proficiency levels - 12 per cent of those in metropolitan schools, 14 per cent in provincial schools, and 24 per cent of students in remote schools failed to reach Level 2.

The score differences equate to about a year of schooling between students in metropolitan and those in remote schools

Points to ponder

- Do you think there are substantial differences in the performance of different groups of students in your school, as described in this chapter?
- One of the things that Australia needs to do to improve our overall scientific literacy is to address the issue of the underachievement of disadvantaged students. What are some ways that schools can help students who are from lower levels of socioeconomic background?

Chapter

3

Sample scientific literacy items and responses

A number of example items and responses set out below are included to show the types of questions included in the assessment and to illustrate the ways in which performance was measured. The examples in this section are taken from the Australian national report on PISA 2006 (Thomson & Greenwood, 2007).[3] No further scientific literacy questions were released from the PISA 2009 cycle. The remaining scientific literacy units remain secure so they can be used as linking items for future PISA cycles.

The fifth question (full credit) of 'Acid Rain' and the fourth and fifth question of 'Greenhouse' are examples of items near the top of the scientific literacy scale that involve interpreting complex and unfamiliar data, imposing a scientific explanation on a complex real-world situation, and applying scientific processes to unfamiliar problems. The first question of 'Clothes', the third and fourth question (partial credit) of 'Greenhouse', the second question of 'Genetically Modified Crops', and the second and fifth question (partial credit) of 'Acid Rain' are illustrative of questions placed around the middle of the scientific literacy proficiency scale, at Levels 3 or 4. The third question from 'Genetically Modified Crops', the second question from 'Clothes' and the third question from 'Acid Rain' are examples of items at the lower end of the scale. Questions are set in simple and relatively familiar contexts and require only the most limited interpretation of a situation.

The units, 'Acid Rain', 'Greenhouse', and 'Clothes' are illustrative of items across more than one scientific competency.

Question 5 in the unit 'Acid Rain', is an example of a partial credit item. Students who provided all the required detail to Question 5 in 'Acid Rain' were given full credit and placed at proficiency level 6, whereas students who provided part of the complete answer to Question 5 were awarded a partial credit and placed at Level 3.

Figure 3.1 shows a visual representation of the location of the sample items on the scientific literacy scale, the competencies that each item has assessed and the difficulty of the item (the number in brackets).

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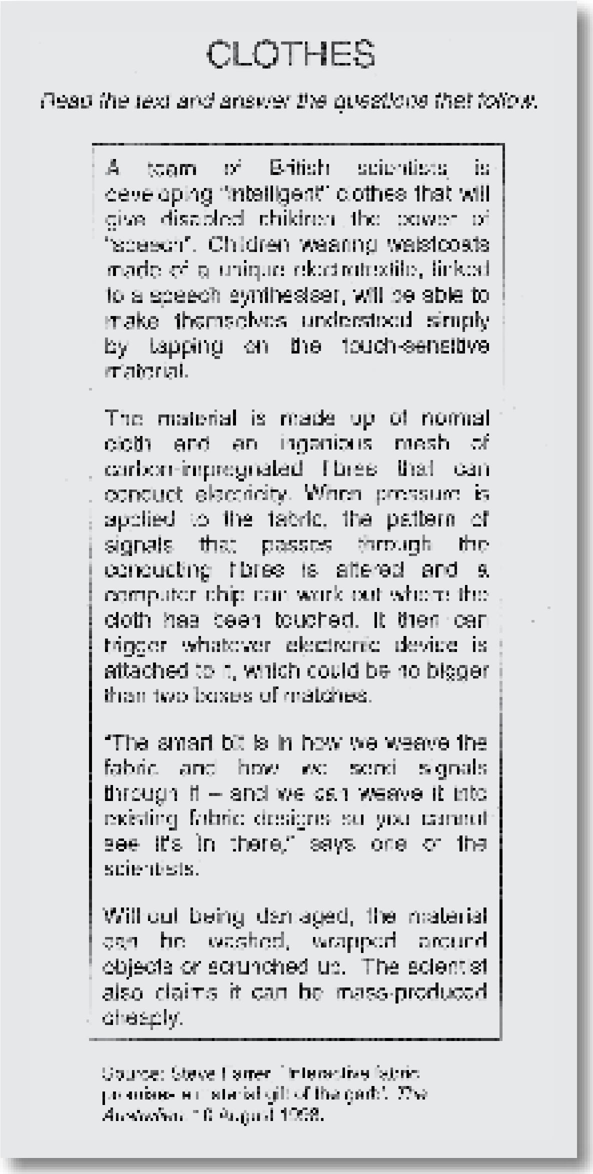
[3] Thomson, S. & Greenwood, L. (2007). *Exploring Scientific Literacy: How Australia measures up*. Camberwell: ACER.

Proficiency level	Competencies		
	Identifying scientific issues	**Explaining phenomena scientifically**	**Using scientific evidence**
6	ACID RAIN Question 5 (717) (full credit)	GREENHOUSE Question 5 (709)	
707.9 score points			
5			GREENHOUSE Question 4 (659) (full credit)
633.3 score points			
4	CLOTHES Question 1 (567)		GREENHOUSE Question 4 (568) (partial credit)
558.7 score points			
3	ACID RAIN Question 5 (513) (partial credit) GENETICALLY MODIFIED CROPS Question 2 (488)	ACID RAIN Question 2 (506)	GREENHOUSE Question 3 (529)
484.1 score points			
2	GENETICALLY MODIFIED CROPS Question 3 (421)		ACID RAIN Question 3 (460)
409.5 score points			
1		CLOTHES Question 2 (399)	
334.9 score points			

Figure 3.1 Sample items and cut-off score points for the scientific literacy proficiency scale

Clothes

Two competencies are assessed in the unit ‘Clothes’, the stimulus for which follows.



CLOTHES

Read the text and answer the questions that follow.

A team of British scientists is developing “intelligent” clothes that will give disabled children the power of “speech”. Children wearing waistcoats made of a unique electrotextile, linked to a speech synthesiser, will be able to make themselves understood simply by tapping on the touch-sensitive material.

The material is made up of normal cloth and an ingenious mesh of carbon-impregnated fibres that can conduct electricity. When pressure is applied to the fabric, the pattern of signals that passes through the conducting fibres is altered and a computer chip can work out where the cloth has been touched. It then can trigger whatever electronic device is attached to it, which could be no bigger than two boxes of matches.

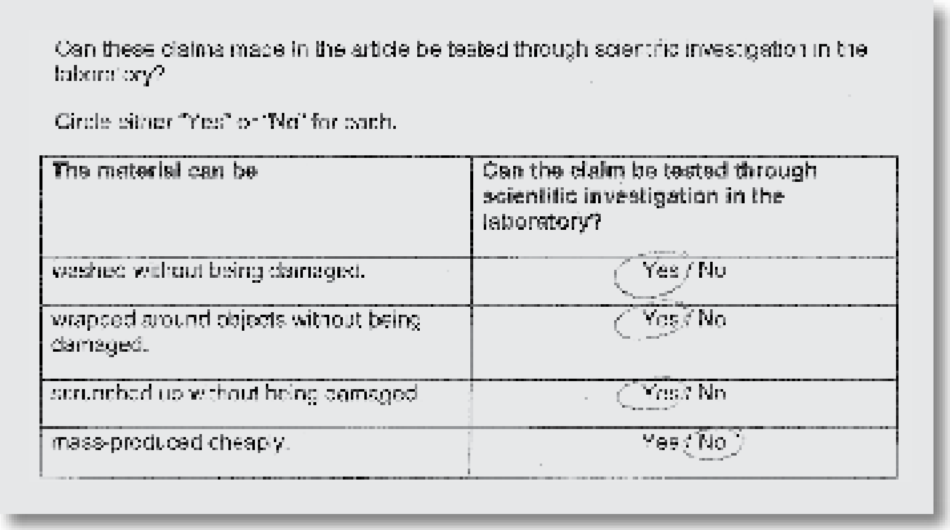
“The smart bit is in how we weave the fabric and how we send signals through it – and we can weave it into existing fabric designs so you cannot see it's in there,” says one of the scientists.

Without being damaged, the material can be washed, wrapped around objects or scrunched up. The scientist also claims it can be mass-produced cheaply.

Source: Steve Farrer, ‘Interactive fabric promises a material gift of the garb’, *The Australian*, 10 August 1998.

Clothes Question 1

The first question, set out below, is a complex multiple-choice question, which assesses the identifying scientific issues competency. Students are asked whether claims made in the article can be tested through scientific investigation in a laboratory, and students need to rely on their knowledge about science, specifically scientific enquiry, to complete this question. The question is set in a social context and is framed in the setting ‘frontiers of science and technology’, as the stimulus refers to the development of a new device, `a waistcoat made of a unique electrotextile´. This question is located at the lower boundary of Level 4 with a difficulty of 567 score points.



Can these claims made in the article be tested through scientific investigation in the laboratory?

Circle either "Yes" or "No" for each.

The material can be	**Can the claim be tested through scientific investigation in the laboratory?**
washed without being damaged.	[✓ Yes] / No
wrapped around objects without being damaged.	[✓ Yes] / No
scrunched up without being damaged	[✓ Yes] / No
mass-produced cheaply.	Yes / [✓ No]

In each of the graphs in this chapter, the bars represent the difference between the proportion of students in the country that answered correctly and the OECD average proportion of students that answered correctly. Countries are asterisked (*) if this proportion is significantly different to the OECD average, and bars are shaded dark green if the proportion is significantly different to the proportion of Australian students. Comparisons will be made to all of the countries used in the previous chapter other than Shanghai-China and Singapore, which did not participate in PISA in 2006.

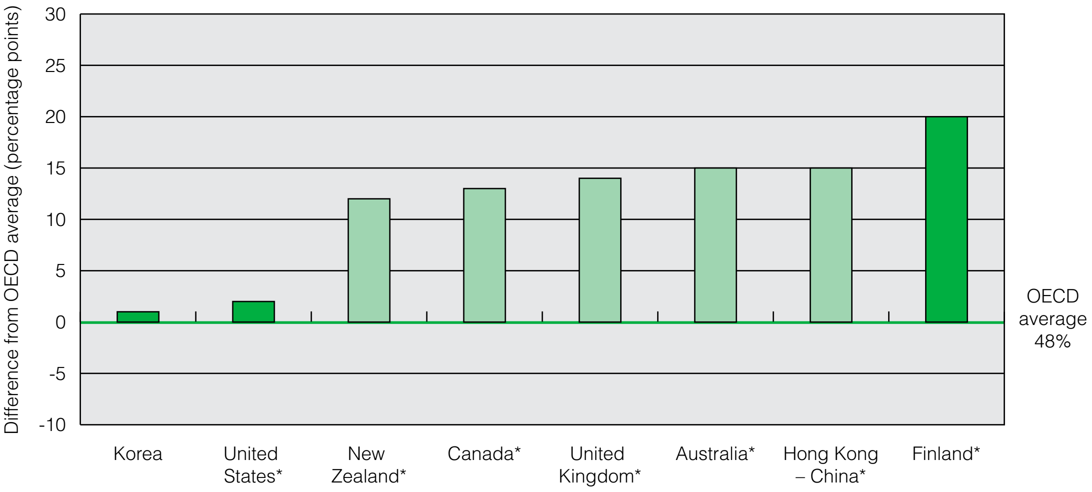
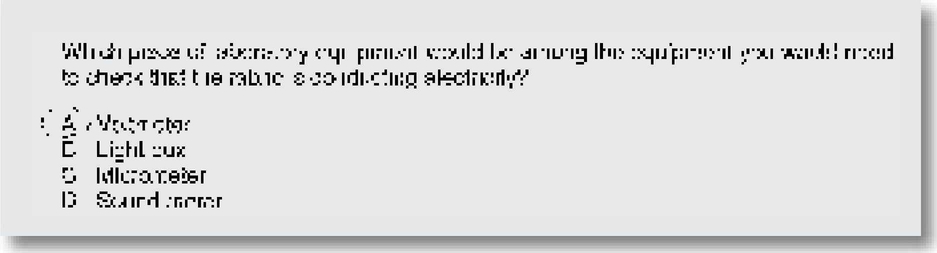


Figure 3.2 Proportion of students providing correct response to Clothes question 1: Australia and comparison countries

- Over 60 per cent of Australian students answered question 1 from the Clothes unit correctly, which is significantly higher than the proportion of students across OECD countries on average.

Clothes Question 2

The second question in the `Clothes´ unit asks the student to recall a single piece of laboratory equipment that could check that the fabric was conducting electricity. This question assesses the ‘explaining phenomena scientifically’ competency and is located in the knowledge of science area – technical systems. The item is framed in the personal setting in the frontiers area. This item is an example of an easy scientific literacy item, with a multiple-choice format, located at the bottom of the proficiency scale at Level 1 (with a difficulty of 399 score points).



Which piece of laboratory equipment would be among the equipment you would need to check that the fabric is conducting electricity?

[✓ A Voltmeter]
B Light box
C Micrometer
D Sound meter

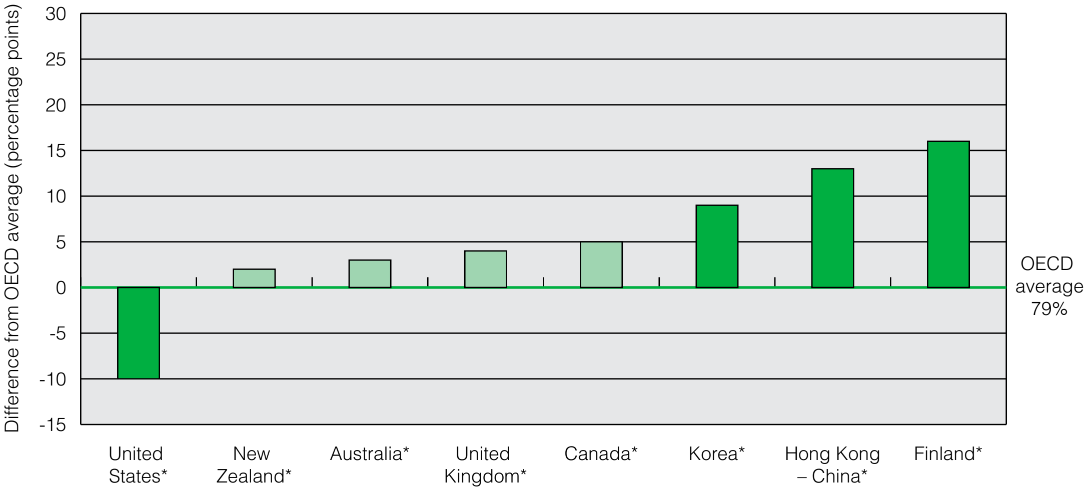
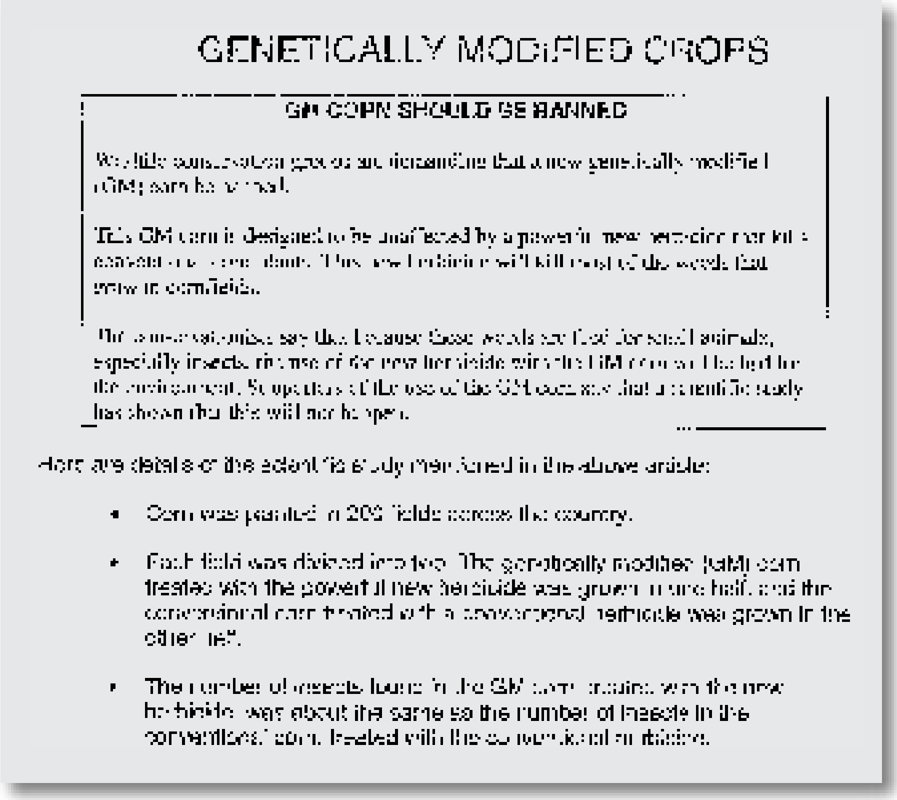


Figure 3.3 Proportion of students providing correct response to Clothes question 2: Australia and comparison countries

- The number of Australian students responding with the correct answer was significantly higher than the average proportion of students across OECD countries.

Genetically Modified Crops

The competency 'identifying scientific issues' was assessed in the unit `Genetically Modified Crops´. The stimulus for `Genetically Modified Crops´ follows. Students are required to demonstrate knowledge about the design of science experiments. The nature of this unit places this question in the frontiers category within a social context.



GENETICALLY MODIFIED CROPS

GM CORN SHOULD BE BANNED

Wildlife conservation groups are demanding that a new genetically modified (GM) corn be banned.

This GM corn is designed to be unaffected by a powerful new herbicide that kills conventional corn plants. This new herbicide will kill most of the weeds that grow in cornfields.

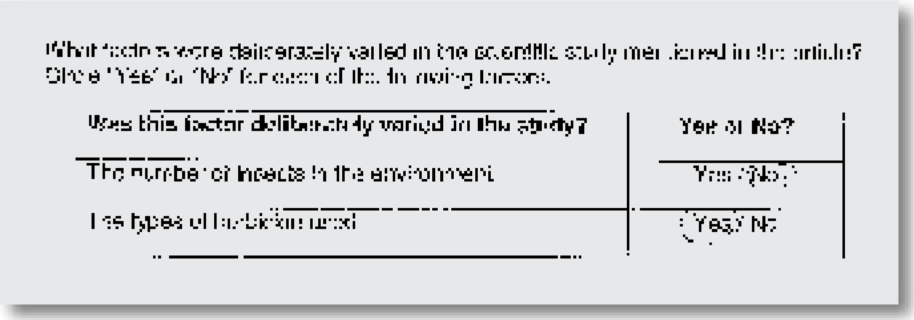
The conservationists say that because these weeds are food for small animals, especially insects, the use of the new herbicide with the GM corn will be bad for the environment. Supporters of the use of the GM corn say that a scientific study has shown that this will not happen.

Here are details of the scientific study mentioned in the above article:

- Corn was planted in 200 fields across the country.
- Each field was divided into two. The genetically modified (GM) corn treated with the powerful new herbicide was grown in one half, and the conventional corn treated with the conventional herbicide was grown in the other half.
- The number of insects found in the GM corn, treated with the new herbicide, was about the same as the number of insects in the conventional corn, treated with the conventional herbicide.

Genetically Modified Crops Question 2

This question is a complex multiple-choice item, which asks students to identify the factors that were varied in the scientific investigation. This item was placed at Level 3 with a difficulty of 488 score points.



What factors were deliberately varied in the scientific study mentioned in the article? Circle 'Yes' or 'No' for each of the following factors.

Was this factor deliberately varied in the study?	Yes or No?
The number of insects in the environment	Yes [✓ No]
The types of herbicide used	[✓ Yes] No

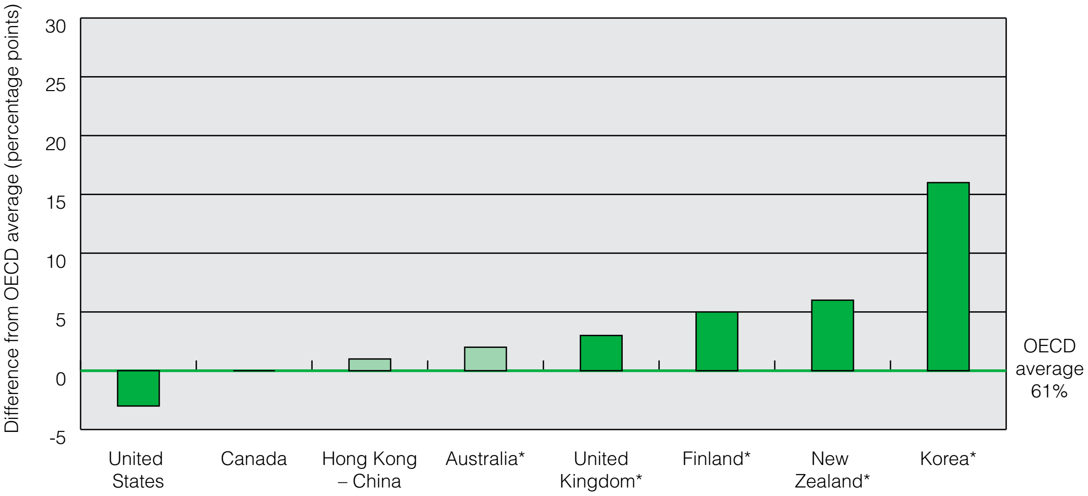
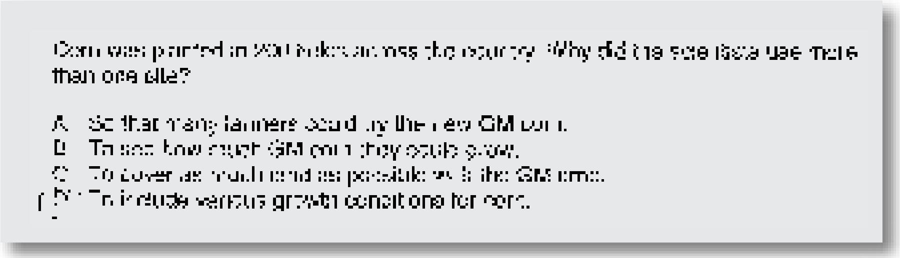


Figure 3.4 Proportion of students providing correct response to Genetically Modified Crops question 2: Australia and comparison countries

- Sixty three percent of Australian students selected the correct answer to question 2 from the Genetically Modified Crops unit, which was a significantly higher proportion of students than the average across from OECD countries.

Genetically Modified Crops Question 3

This multiple-choice item, located at Level 2 with 421 score points, asks students a simple question about varying conditions in a scientific investigation.



Corn was planted in 200 fields across the country. Why did the scientists use more than one site?

A So that many farmers could try the new GM corn.
B To see how much GM corn they could grow.
C To cover as much land as possible with the GM crop.
[✓ D] To include various growth conditions for corn.

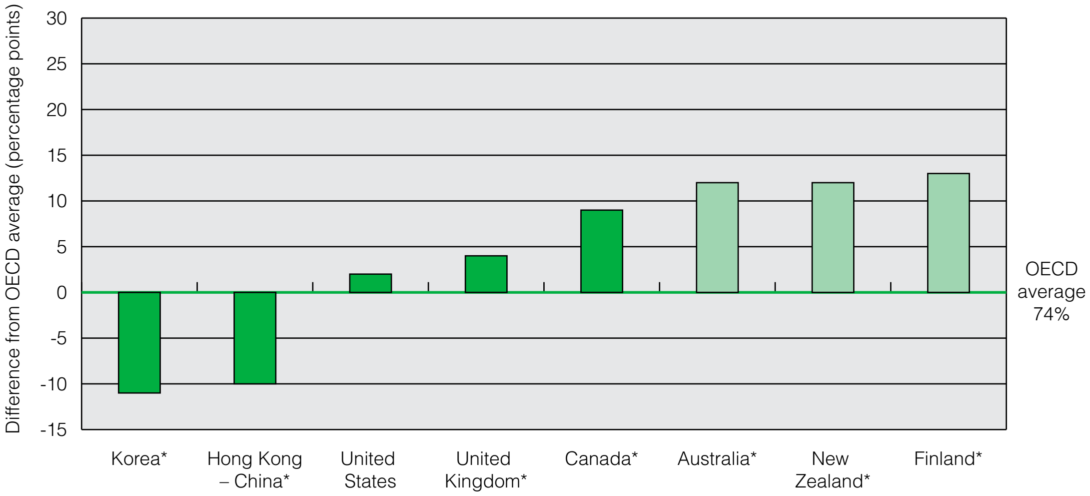


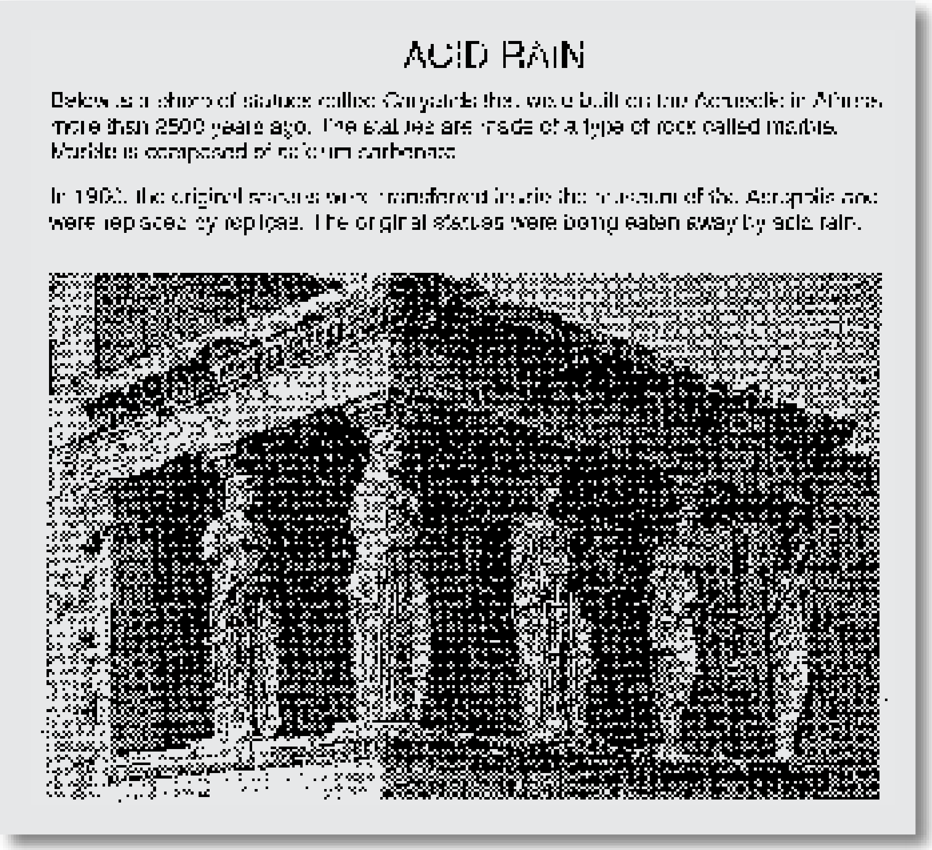
Figure 3.5 Proportion of students providing correct response to Genetically Modified Crops question 3: Australia and comparison countries

- A large proportion (86%) of Australian students answered question 3 from the unit Genetically Modified Crops correctly. This was a significantly better performance compared to that of students from Canada, the United Kingdom, the United States, Hong-Kong-China and Korea, as well as the average across OECD countries.

Acid Rain

There are three cognitive questions in the unit `Acid Rain´, which assess each of the three competencies.

The `Acid Rain´ stimulus features a photograph of the Caryatids statues from the Acropolis in Athens and a short paragraph of text, as shown here.



ACID RAIN

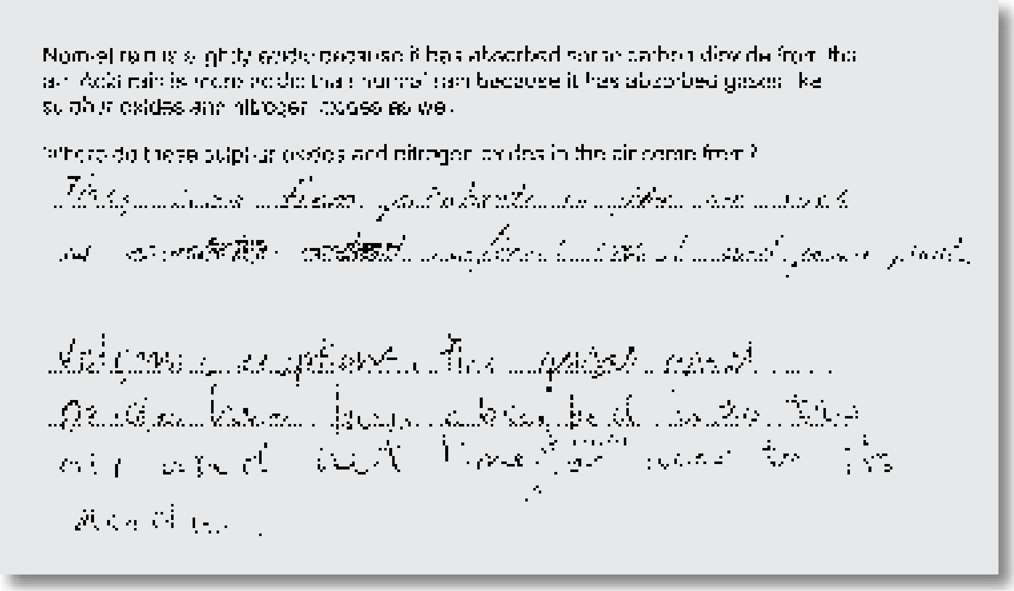
Below is a photo of statues called Caryatids that were built on the Acropolis in Athens more than 2500 years ago. The statues are made of a type of rock called marble. Marble is composed of calcium carbonate.

In 1980, the original statues were transferred inside the museum of the Acropolis and were replaced by replicas. The original statues were being eaten away by acid rain.

Acid Rain Question 2

This question assesses the competency ‘explaining phenomena scientifically’. To answer this question, students must have knowledge of science, and in particular of physical systems. The context of this question relates to hazards and it is framed in a social setting. This item was placed at Level 3 with a difficulty of 506 score points.

In the stem of the question, students are told `acid rain is more acidic than normal rain because it has absorbed gases like sulphur oxides and nitrogen oxides as well´. They are asked where sulphur oxides and nitrogen oxides in the air come from. Responses were coded correct if they included any one of car exhausts, factory emissions, burning fossil fuels (such as oil and coal), gases from volcanoes, or other similar things.



Normal rain is slightly acidic because it has absorbed some carbon dioxide from the air. Acid rain is more acidic than normal rain because it has absorbed gases like sulphur oxides and nitrogen oxides as well.

Where do these sulphur oxides and nitrogen oxides in the air come from?

Acid Rain Scoring – Question 2

Full Credit
Any one of car exhausts, factory emissions, burning fossil fuels such as oil and coal, gases from volcanoes or other similar things.

- Burning coal and gas.
- Oxides in the air come from pollution from factories and industries.
- Volcanoes.
- Fumes from power plants. *["Power plants" is taken to include power plants that burn fossil fuels.]*
- They come from the burning of materials that contain sulfur and nitrogen.

Partial Credit
Responses that include an incorrect as well as a correct source of the pollution.

- Fossil fuel and nuclear power plants. *[Nuclear power plants are not a source of acid rain.]*
- The oxides come from the ozone, atmosphere and meteors coming toward Earth. Also the burning of fossil fuels.

OR Responses that refer to "pollution" but do not give a source of pollution that is a significant cause of acid rain.

- Pollution
- The environment in general, the atmosphere we live in – e.g., pollution.
- Gasification, pollution, fires, cigarettes. *[It is not clear what is meant by "gasification"; "fires" is not specific enough; cigarette smoke is not a significant cause of acid rain.]*
- Pollution such as from nuclear power plants.

No Credit
Other responses, including responses that do not mention "pollution" and do not give a significant cause of acid rain.

- They are emitted from plastics.
- They are natural components of air.
- Cigarettes.
- Coal and oil. *[Not specific enough – no reference to "burning".]*
- Nuclear power plants.
- Industrial waste. *[Not specific enough.]*

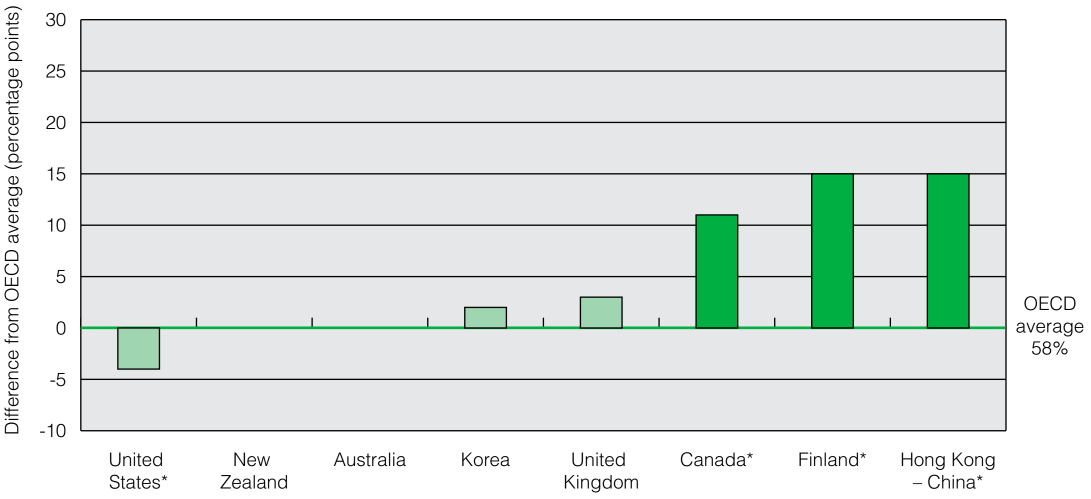
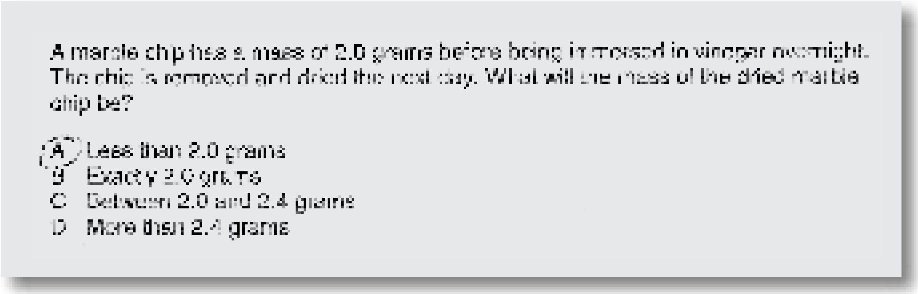


Figure 3.6 Proportion of students providing correct response to Acid Rain question 2: Australia and comparison countries

- Over half of the Australian students provided a response that received credit (either full or partial) on this item, which was the same as the OECD average.

Acid Rain Question 3

The next question assesses the competency 'using scientific evidence' and is placed at Level 2 with a difficulty of 460 score points. The science-related situation of this question relates to a hazard that is caused by humans and is set in a personal context. Knowledge of physical systems is required to successfully answer the question. Students were provided with a simple model showing the influence of acid rain on marble and were asked to draw a conclusion about the effects of vinegar on marble.



A marble chip has a mass of 2.0 grams before being immersed in vinegar overnight. The chip is removed and dried the next day. What will the mass of the dried marble chip be?

[✓ A] Less than 2.0 grams
B Exactly 2.0 grams
C Between 2.0 and 2.4 grams
D More than 2.4 grams

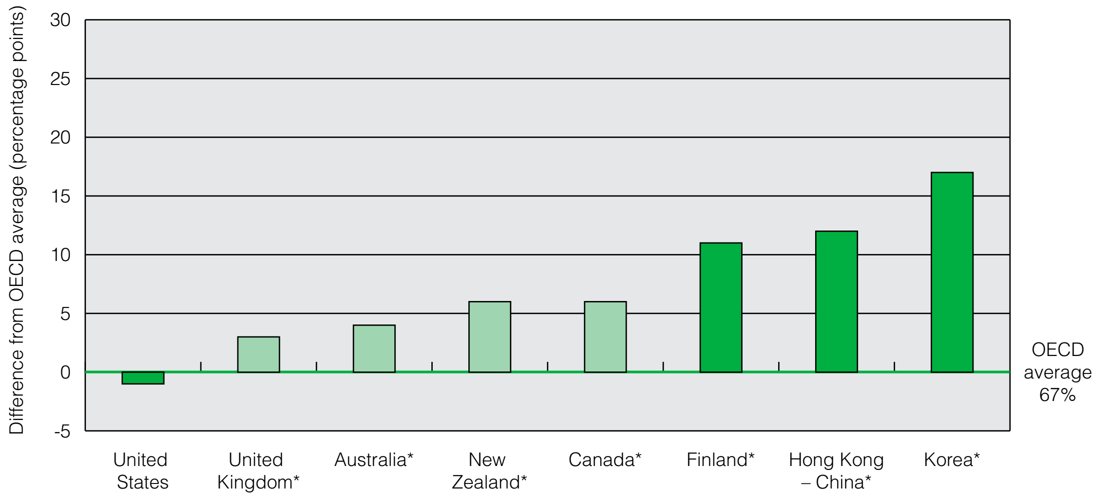


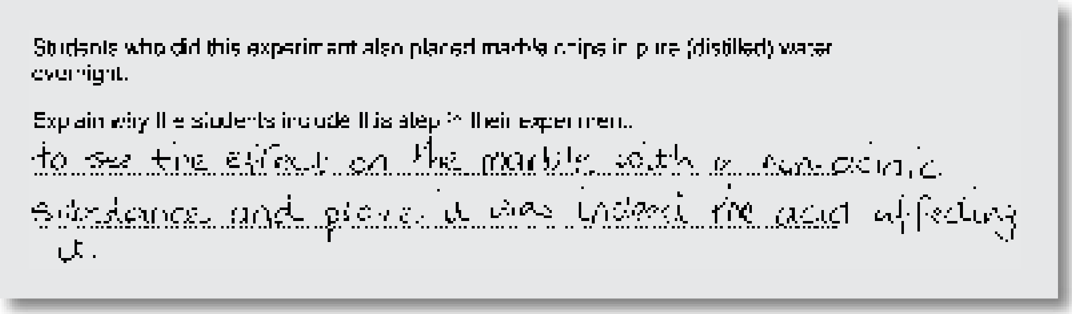
Figure 3.7 Proportion of students providing correct response to Acid Rain question 3: Australia and comparison countries

- Just over 70 per cent of Australian students answered question 3 from the Acid Rain unit correctly, which is significantly higher than the average proportion of students from OECD countries.

Acid Rain Question 5

The final cognitive question in this unit assesses the competency 'identifying scientific issues' and involves knowledge about scientific enquiry. The question is set in a personal context and the situation involves hazards that humans have to overcome. Students have to demonstrate an ability to understand scientific investigation and the purpose of using a control variable. In the previous question students were provided information about the effects of vinegar on marble. In this question, students were asked to explain why some chips were placed in distilled water overnight.

This question is an example of a partial credit item. To achieve full credit, students had to explain that the marble chips placed in distilled water were to compare with the test of vinegar and marble, to show that the acid (vinegar) was necessary for the reaction to occur. A full credit response was located at Level 6 with a difficulty of 717 score points. Below is an example of a response that achieved full credit.

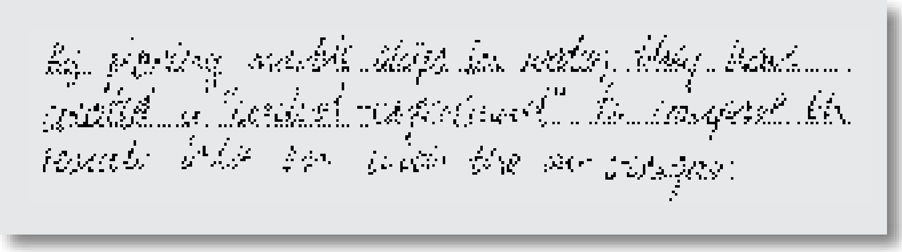


Students who did this experiment also placed marble chips in pure (distilled) water overnight.

Explain why the students include this step in their experiment.

to see the effect on the marble with a non-acidic substance and prove it was indeed the acid affecting it.

To achieve a partial credit, with a difficulty of 513 score points (Level 3), students provided a response that included a comparison with the test of vinegar and marble, but did not make clear that this was being done to show that the acid (vinegar) is necessary for the reaction. A partial credit response is shown below.



By placing marble chips in water, they have created a "control experiment" to compare the results [illegible] [illegible] [illegible] the [illegible] vinegar:

Acid Rain Scoring – Question 5

Full Credit To compare with the test of vinegar and marble and so show that the acid (vinegar) is necessary for the reaction.
◗ To make sure that rainwater must be acidic like acid rain to cause this reaction.
◗ To see whether there are other reasons for the holes in the marble chips.
◗ Because it shows that the marble chips don't just react with any fluid since water is neutral.
Partial Credit To compare with the test of vinegar and marble, but it is not made clear that this is being done to show that the acid (vinegar) is necessary for the reaction.
◗ To compare with the other test tube.
◗ To see whether the marble chip changes in pure water.
◗ The students included this step to show what happens when it rains normally on the marble.
◗ Because distilled water is not acid.
◗ To act as a control.
◗ To see the difference between normal water and acidic water (vinegar).
No Credit Other responses.
◗ To show the distilled water wasn't an acid.

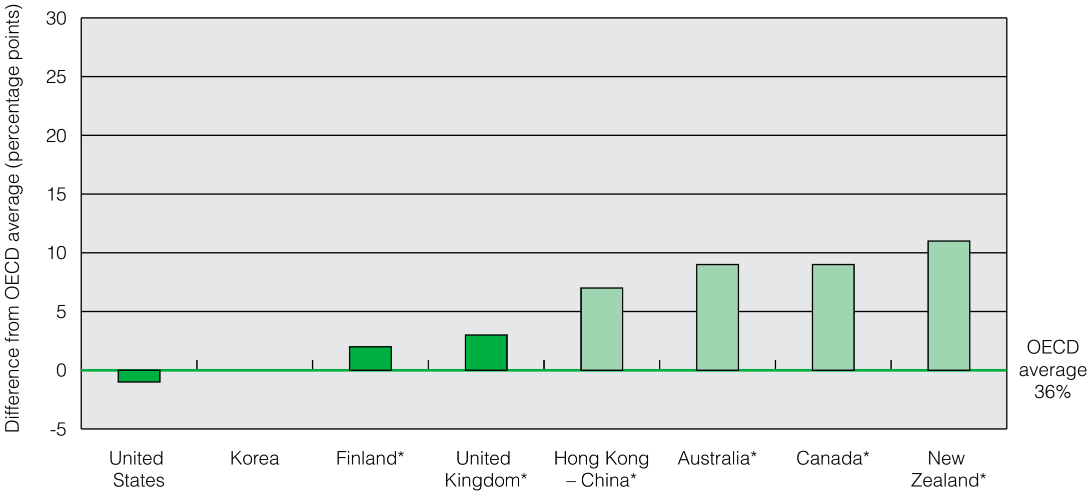
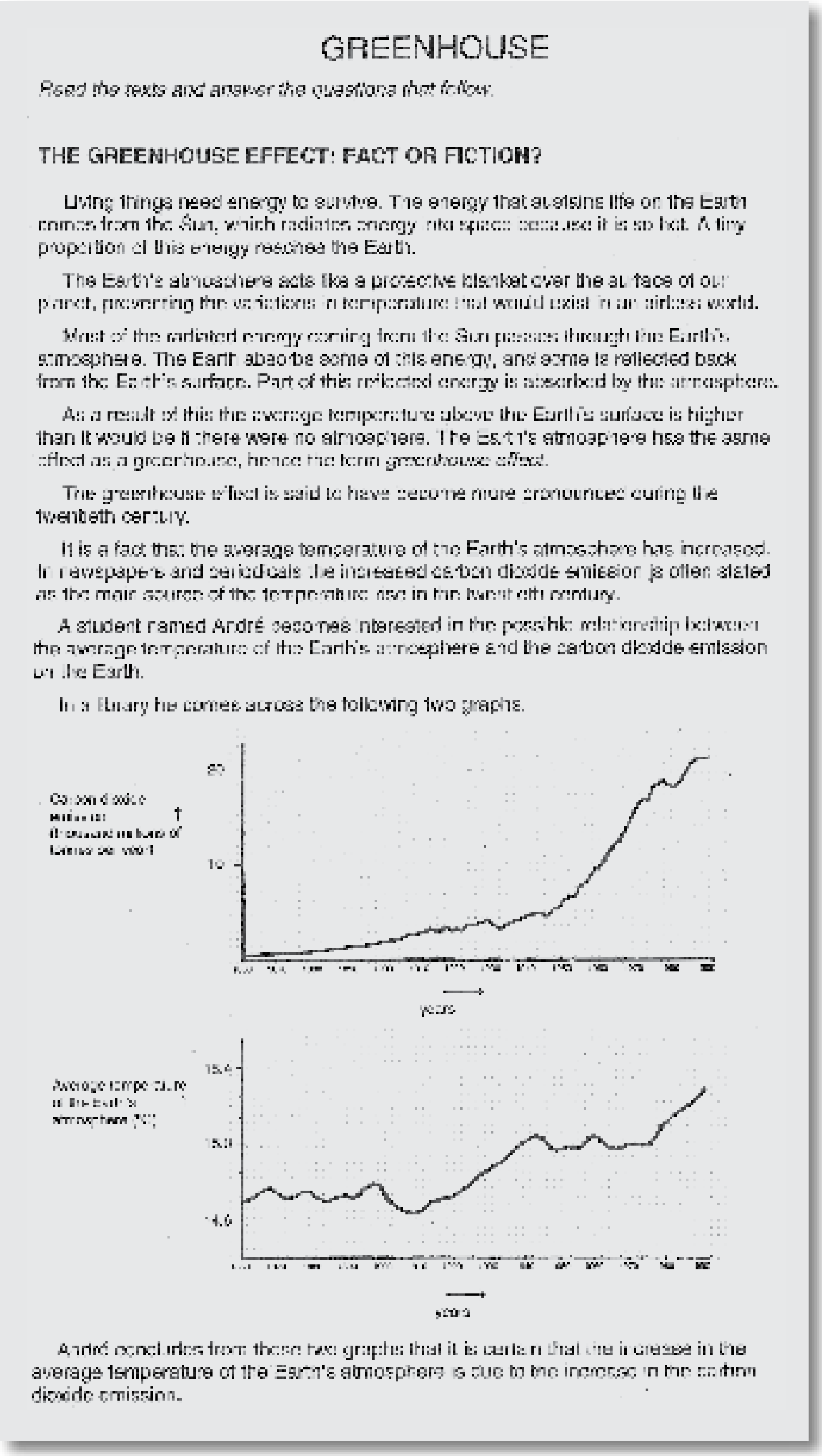


Figure 3.8 Proportion of students providing correct response to Acid Rain question 5: Australia and comparison countries

- Australia compared quite well on this item compared to students in the other countries reported here.

Greenhouse

The unit `Greenhouse´ assesses two competencies, ‘using scientific evidence’ and ‘explaining phenomena scientifically’, from an environmental perspective with a global focus.



GREENHOUSE

Read the texts and answer the questions that follow.

THE GREENHOUSE EFFECT: FACT OR FICTION?

Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth.

The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world.

Most of the radiated energy coming from the Sun passes through the Earth's atmosphere. The Earth absorbs some of this energy, and some is reflected back from the Earth's surface. Part of this reflected energy is absorbed by the atmosphere.

As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term *greenhouse effect*.

The greenhouse effect is said to have become more pronounced during the twentieth century.

It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

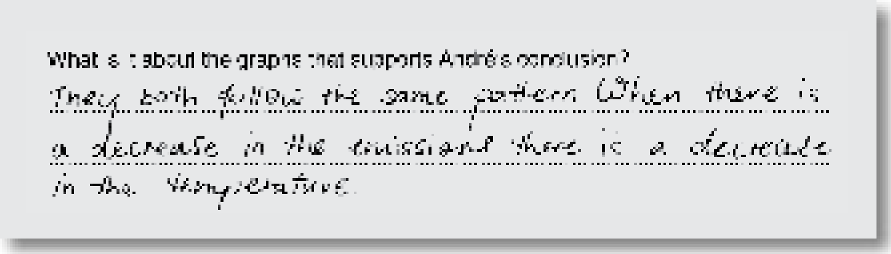
A student named André becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth.

In a library he comes across the following two graphs.

André concludes from these two graphs that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

Greenhouse Question 3

This question is an open constructed-response item assessing the ‘using scientific evidence’ competency. It also assesses students´ knowledge about scientific explanation. For this question, students are asked to identify information in two graphs that support a conclusion. Students must interpret the graphs to conclude there is an increase in both average temperature and carbon dioxide emissions. This question is placed at Level 3 with a difficulty of 529 score points.



What is it about the graphs that supports André's conclusion?

They both follow the same pattern When there is a decrease in the emissions and there is a decrease in the temperature.

Greenhouse Scoring – Question 3

Full Credit
Refers to the increase of both (average) temperature and carbon dioxide emission

- As the emissions increased the temperature increased.
- Both graphs are increasing.
- Because in 1910 both the graphs began to increase.
- Temperature is rising as CO^2 is emitted.
- The information lines on the graphs rise together.
- Everything is increasing.
- The more CO^2 emission, the higher the temperature.

OR Refers (in general terms) to a positive relationship between temperature and carbon dioxide emission.

- The amount of CO^2 and average temperature of the Earth is directly proportional.
- They have a similar shape indicating a relationship. *[Note: This code is intended to capture students’ use of terminology such as ‘positive relationship’, ‘similar shape’ or ‘directly proportional’; although the following sample response is not strictly correct, it shows sufficient understanding to be given credit here.]*

No Credit
Refers to the increase of either the (average) temperature or the carbon dioxide emission.

- The temperature has gone up.
- CO^2 is increasing.
- It shows the dramatic change in the temperatures.

OR Refers to temperature and carbon dioxide emission without being clear about the nature of the relationship.

- The carbon dioxide emission (graph 1) has an effect on the earth’s rising temperature (graph 2).
- The carbon dioxide is the main cause of the increase in the earth’s temperature.

OR Other responses.

- The carbon dioxide emission is greatly rising more than the average Earth’s temperature. *[Note: This answer is incorrect because the extent to which the CO^2 emission and the temperature are rising is seen as the answer, rather than that they are both increasing.]*
- The rise of CO^2 over the years is due to the rise of the temperature of the Earth’s atmosphere.
- The way the graph goes up.
- There is a rise.

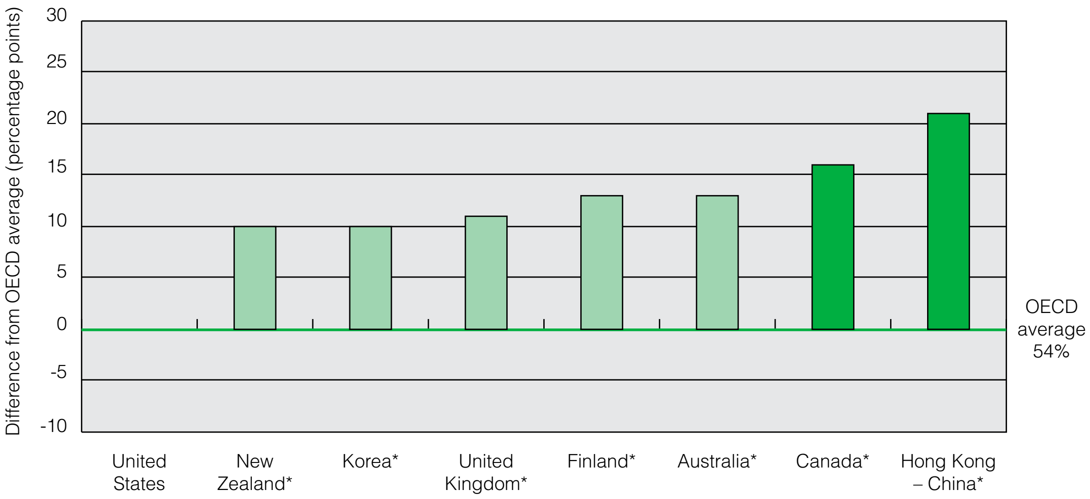


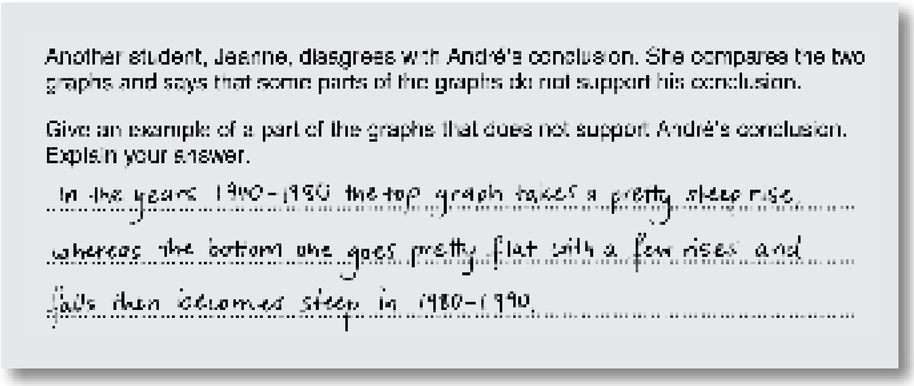
Figure 3.9 Proportion of students providing correct response to Greenhouse question 3: Australia and comparison countries

- For question 3 from the Greenhouse unit, two-thirds of Australian students selected the correct answer.

Greenhouse Question 4

This next question is an open constructed-response item with full and partial credit awarded. It assesses the competency 'using scientific evidence' and students must rely on their knowledge about scientific explanation.

Students are asked to provide an example of the two graphs that do not support André´s conclusion. To achieve full credit students must identify a segment on both graphs in which the curves are not both descending or both climbing and give a corresponding explanation. A full credit response was located at Level 5 with 659 score points. The following example shows a response that achieved full credit.



Another student, Jeanne, disagrees with André's conclusion. She compares the two graphs and says that some parts of the graphs do not support his conclusion.

Give an example of a part of the graphs that does not support André's conclusion. Explain your answer.

In the years 1940-1950 the top graph takes a pretty steep rise, whereas the bottom one goes pretty flat with a few rises and falls then becomes steep in 1980-1990.

Greenhouse Scoring – Question 4

Full Credit
Refers to one particular part of the graphs in which the curves are not both descending or both climbing and gives the corresponding explanation.

- In 1900–1910 (about) CO^2 was increasing, whilst the temperature was going down.
- In 1980–1983 carbon dioxide went down and the temperature rose.
- The temperature in the 1800's is much the same but the first graph keeps climbing.
- Between 1950 and 1980 the temperature didn't increase but the CO^2 did.
- From 1940 until 1975 the temperature stays about the same but the carbon dioxide emission shows a sharp rise.
- In 1940 the temperature is a lot higher than in 1920 and they have similar carbon dioxide emissions.

Partial Credit
Mentions a correct period, without any explanation.

- 1930–1933.
- Before 1910.

OR Mentions only one particular year (not a period of time), with an acceptable explanation.

- In 1980 the emissions were down but the temperature still rose.

OR Gives an example that doesn't support André's conclusion but makes a mistake in mentioning the period. *[Note: There should be evidence of this mistake – e.g. an area clearly illustrating a correct answer is marked on the graph and then a mistake made in transferring this information to the text.]*

- Between 1950 and 1960 the temperature decreased and the carbon dioxide emission increased.

OR Refers to differences between the two curves, without mentioning a specific period.

- At some places the temperature rises even if the emission decreases.
- Earlier there was little emission but nevertheless high temperature.
- When there is a steady increase in graph 1, there isn't an increase in graph 2, it stays constant. *[Note: It stays constant "overall".]*
- Because at the start the temperature is still high where the carbon dioxide was very low.

OR Refers to an irregularity in one of the graphs.

- It is about 1910 when the temperature had dropped and went on for a certain period of time.
- In the second graph there is a decrease in temperature of the Earth's atmosphere just before 1910.

OR Indicates difference in the graphs, but explanation is poor.

- In the 1940's the heat was very high but the carbon dioxide very low. *[Note: The explanation is very poor, but the difference that is indicated is clear.]*

No Credit
Refers to an irregularity in a curve without referring specifically to the two graphs.

- It goes a little up and down.
- It went down in 1930.

OR Refers to a poorly defined period or year without any explanation.

- The middle part.
- 1910.

OR Other responses.

- In 1940 the average temperature increased, but not the carbon dioxide emission.
- Around 1910 the temperature has increased but not the emission.

Students were awarded a partial credit result if they mentioned the correct period, but without any explanation; mentioned only one particular year (not a period of time) with an acceptable explanation; or referred to differences between the two curves without mentioning a specific period. A partial credit response was located at Level 4 with 568 score points.

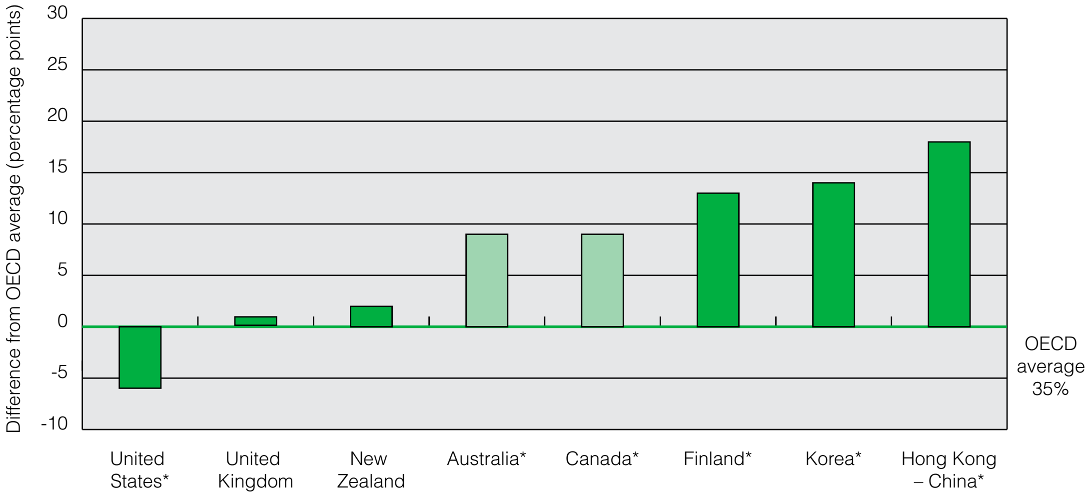
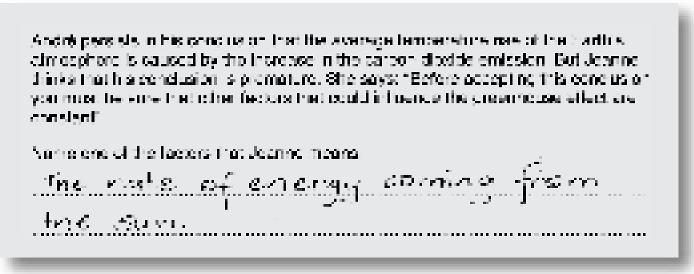


Figure 3.10 Proportion of students providing correct response to Greenhouse question 4: Australia and comparison countries

- Over 40 per cent of the Australian students provided a correct response to this question.

Greenhouse Question 5

The final question in the unit `Greenhouse´ assesses the competency ‘explaining phenomena scientifically’ and students´ knowledge of Earth and space systems. This question is one of the harder scientific literacy items to complete, placed at Level 6 with a difficultly of 709 score points. In this question students must provide a factor that could influence the greenhouse effect. The following example shows a correct response.



André persists in his conclusion that the average temperature rise of the Earth's atmosphere is caused by the increase in the carbon dioxide emission. But Jeanne thinks that his conclusion is premature. She says: "Before accepting this conclusion you must be sure that other factors that could influence the greenhouse effect are constant".

Name one of the factors that Jeanne means.

The rate of energy coming from the sun.

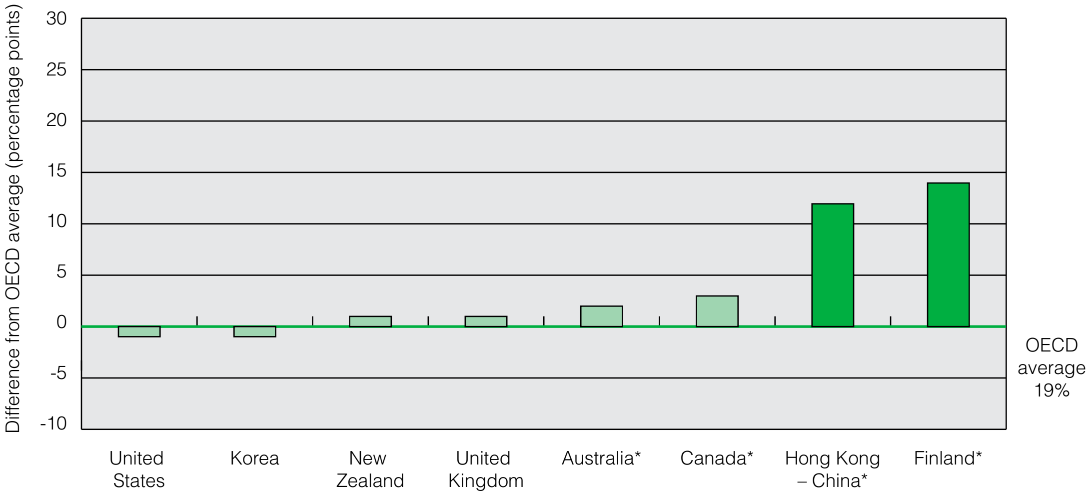


Figure 3.11 Proportion of students providing correct response to Greenhouse question 5: Australia and comparison countries

- About 20 per cent of Australian students answered question 5 from the Greenhouse unit correctly, which is significantly higher than the average proportion of students across OECD countries.

Chapter 4

Attitudes, engagement and motivation

An important outcome of science education is the attitudes students have towards science, how they respond to scientific issues, the motivation they have to excel in their science subject(s), their interest in learning science at school and beyond school and their motivation to pursue a science related course or career. The focus on scientific literacy as the major domain in PISA 2006 provided an opportunity to examine the attitudes, interest and engagement of 15-year-old students in relation to science.

This chapter describes four areas that provide a summary of students´ general appreciation of science, their attitudes towards science, their personal beliefs as science learners and their responsibility towards selected science-related issues that have local and global consequences.

The four constructs – support for scientific enquiry; self-belief as science learners; interest in science; and responsibility towards resources and environments – are summarised in Figure 4.1.

Support for scientific enquiry

Students show they can:

- Acknowledge the importance of considering different scientific perspectives and arguments.
- Support the use of factual information and rational explanations.
- Express the need for logical and careful processes in drawing conclusions.

Measures include: questions on support for scientific enquiry (that were integrated into the assessment of science performance); general value of science; personal value of science.

Student beliefs about learning science

Students believe they can:

- Handle scientific tasks effectively.
- Overcome difficulties to solve scientific problems.
- Demonstrate strong scientific abilities.

Measures include: questions on self-efficacy in science; self-concept in science.

Interest, engagement and motivation in science

Students show that they:

- Indicate curiosity in science and science-related issues and endeavours.
- Demonstrate willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods.
- Demonstrate willingness to seek information and have an ongoing interest in science, including consideration of science related careers.

Measures include: questions on interest in learning science topics (that were integrated into the assessment of science performance); general interest in science; importance of learning science; enjoyment of science; instrumental motivation to learn science and future-oriented science motivation.

Responsibility towards resources and environments

Students show they can:

- Show a sense of personal responsibility for maintaining a sustainable environment.
- Demonstrate awareness of the environmental consequences of individual actions.
- Demonstrate willingness to take action to maintain natural resources.

Measures include: questions on responsibility for sustainable development; awareness of environmental issues; level of concern for environmental issues; optimism for the evolution of selected environmental issues.

Figure 4.1 Summary of PISA 2006 assessment of attitudes (OECD, 2007, p.123)[4]

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[4] OECD. (2007). *PISA 2006: Science competencies for tomorrow's world (Volume 1)*. Paris: OECD.

Support for scientific enquiry

General value of science

PISA collected information on students´ perception of the general value of science. A strong general value of science relates to students valuing the contribution of science and technology, for understanding the natural and constructed world, and for the improvement of natural, technological and social conditions of life. Students were asked to indicate their level of agreement (strongly agree; agree; disagree; and strongly disagree) with the following statements:

- Advances in science and technology usually improve people´s living conditions.
- Science is important for helping us to understand the natural world.
- Advances in science and technology usually help improve the country.
- Science is valuable to society.
- Advances in science and technology usually bring social benefits.

These statements were used to create an index on the general value of science. Values on this and other indices described in this chapter were standardised so that the mean of zero represented the mean of the OECD student population. Higher scores on the index indicated that students responded with higher levels on the particular index than on average across the OECD.

Australia's mean index score was slightly lower than the OECD average, with male students scoring at the OECD average and females significantly below.

Figure 4.2 shows the proportion of Australian students agreeing (either strongly agree or agree) with each of the statements on the value of science index.

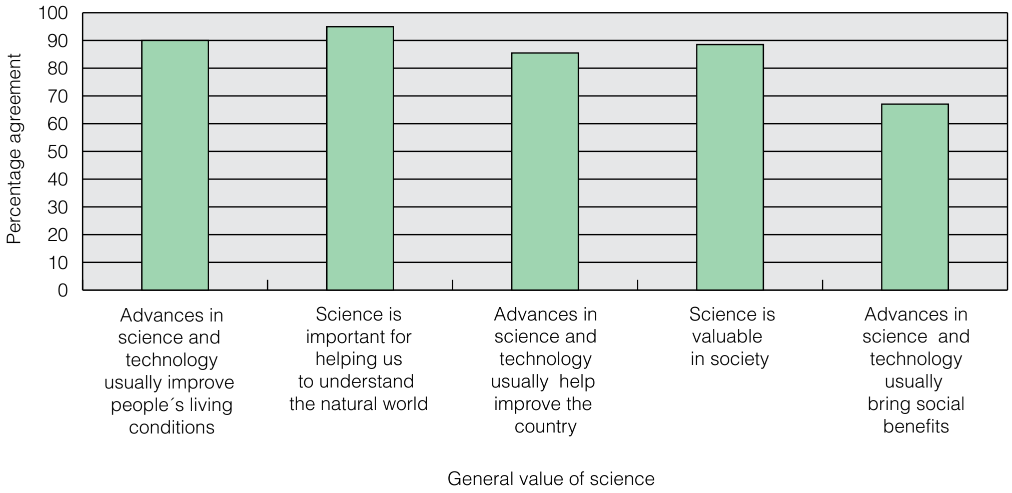
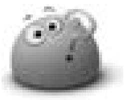


Figure 4.2 Australian student agreement to the value of science items

- There was a moderately strong relationship between scores on this index and scientific literacy achievement. Australian students who reported the highest levels on this index scored, on average, 98 points higher than students who scored in the lowest quarter of this index. This is the equivalent of about three school years.

Of interest is that although there is generally a high agreement with these items, the exception is the item that argues science and technology usually bring social benefits. Why do you think that a third of Australian students disagreed with this item?



Personal value of science

The majority of Australian students perceived science as generally important. The *personal value of science* index considered whether science was important in a student´s own life and affected their behaviour. The personal value of science related to students´ value of science and the scientific advancement of understanding the world for their own sake, and the usefulness of science and scientific inquiry at an individual level.

Five items were used to measure perceptions of the personal value of science. Students were asked to indicate the extent of their agreement (strongly agree; agree; disagree; and strongly disagree) with the following statements:

- Some concepts in science help me see how I relate to other people.
- I will use science in many ways when I am an adult.
- Science is very relevant to me.
- I find that science helps me to understand the things around me.
- When I leave school there will be many opportunities for me to use science.

Figure 4.3 shows the proportion of Australian students agreeing (either strongly agree or agree) with each of the statements on the personal value of science index.

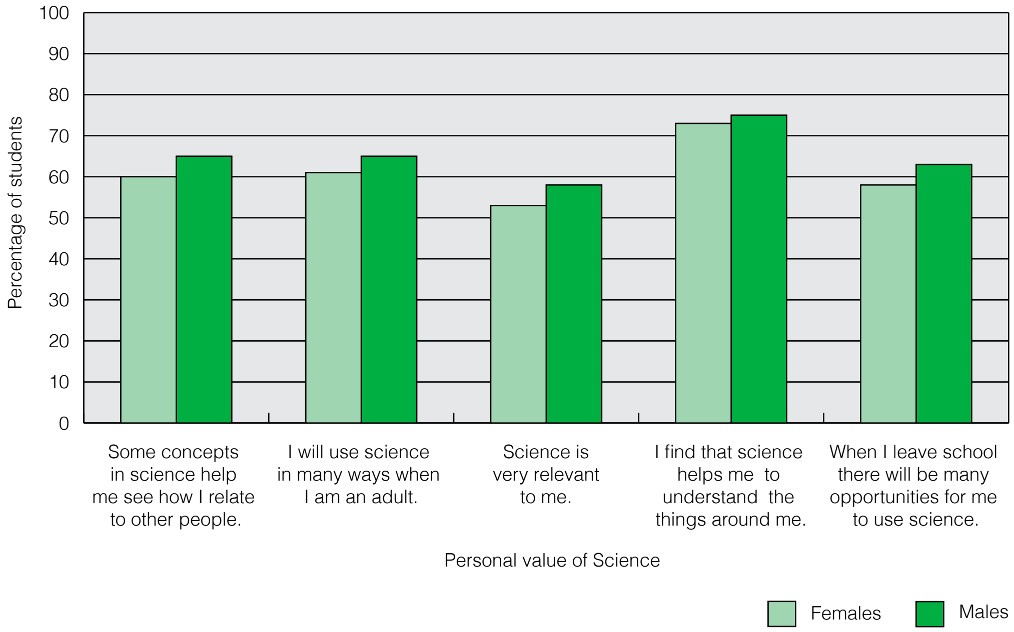
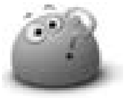


Figure 4.3 Australian student agreement to the personal value of science items, by gender

- While most students agreed that science helps them understand the world around them, there was least agreement with “science is very relevant to me”.



Why do you think it is that students do not see science as personally relevant? Can you think of ways to address this in the classroom?

There was a moderately strong relationship between scores on this index and scientific literacy achievement. Australian students who reported the highest levels on this index scored, on average, 94 points higher than students who scored in the lowest quarter of this index. This is the equivalent of about three school years.

Students´ beliefs and learning science

Of all the attitudinal and student belief constructs examined in PISA 2006 for Australian students, self-efficacy and self-concept were found to have the strongest positive associations with scientific literacy. Self-efficacy and self-concept in science appear to play an important role in influencing behaviour.

Self-efficacy in science

Students´ feelings of confidence about a specific problem are important to an individual´s capacity to solve that problem. Eight items measuring the student´s confidence to perform science related tasks were used to assess self-efficacy in science for PISA 2006. These statements cover important themes identified in the scientific literacy framework. Students were asked how confidently they could:

- Recognise the science question that underlies a newspaper report on a health issue.
- Explain why earthquakes occur more frequently in some areas than in others.
- Describe the role of antibiotics in the treatment of disease.
- Identify the science question associated with the disposal of garbage.
- Predict how changes to an environment will affect the survival of certain species.
- Discuss how new evidence can lead you to change your understanding about the possibility of life on Mars.
- Interpret the scientific information provided on the labelling of food items.
- Identify the better of two explanations for the formation of acid rain.

Students were asked to respond using a scale ranging from “could do easily”, “could do with some effort” to “would struggle on my own” to “couldn’t do it”. Figure 4.4 shows the proportion of students in Australia who thought they could do it easily, or with some effort, and the proportion that would struggle or not be able to do it, along with the average scores for students in each category. On most items students showed reasonable self-efficacy.

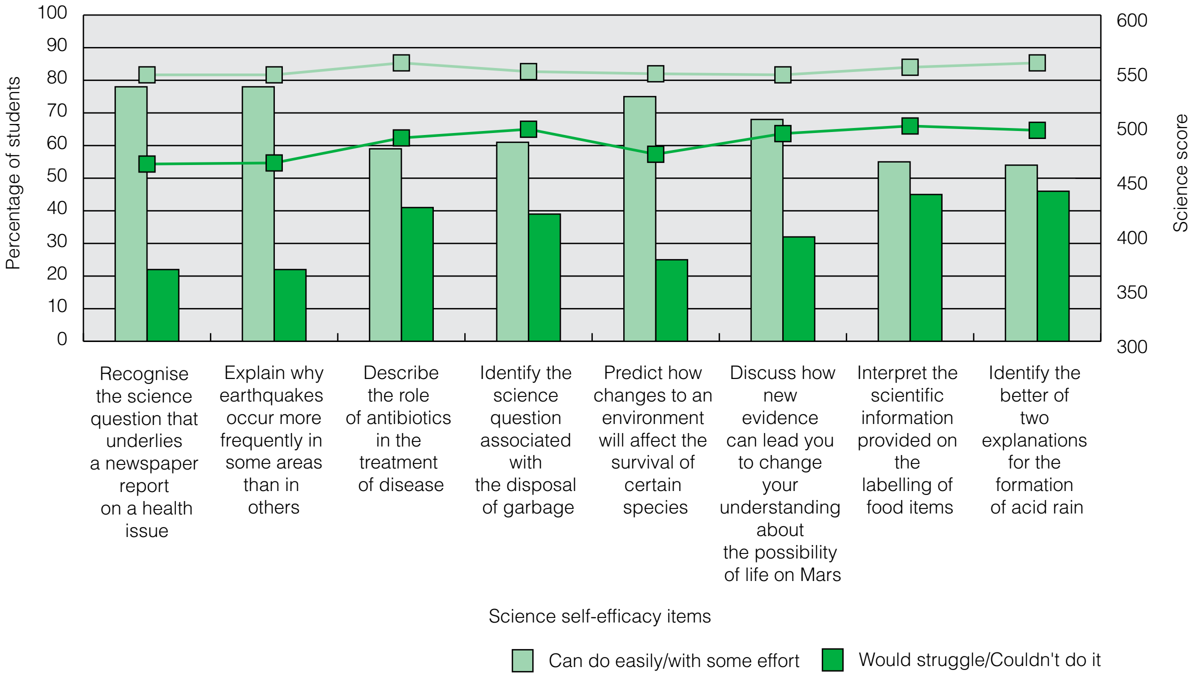
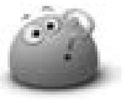


Figure 4.4 Australian student agreement to the science self-efficacy items

- There was a strong positive relationship between self-efficacy in science and scientific literacy performance. Students in the highest quarter of this index scored, on average, 130 points higher than students in the lowest quarter on this index. This is the equivalent of almost four years of schooling.
- In the majority of countries, males had stronger levels of self-efficacy than females. This was also the case in Australia – both males and females had levels of self-efficacy significantly higher than the OECD average, with the level for males significantly higher than the level for females.

Given the pervasiveness of antibiotics in modern life, do you find the proportion of 15 year-old students who would struggle with or not be able to answer questions describing the role of antibiotics in the treatment of disease surprising?



Self-concept in science

PISA collected information on students' beliefs about their competence in science. If students believe in their own capacities, they will be more willing to make the necessary investments in learning, with the outcome being improved performance.

Six items on science self-concept were used in PISA 2006 to examine this construct. Students were asked about their experience in learning topics by indicating their level of agreement (strongly agree; agree; disagree; and strongly disagree) with the following statements:

- Learning advanced science topics would be easy for me.
- I can usually give good answers to test questions on science topics.
- I learn science topics quickly.
- Science topics are easy for me.
- When I am being taught science, I can understand the concepts very well.

- I can easily understand new ideas in science.

Responses to these items were combined to form an index of science self-concept. Figure 4.5 shows the proportion of Australian students agreeing (either strongly agree or agree) with each of the statements on the science self-concept index.

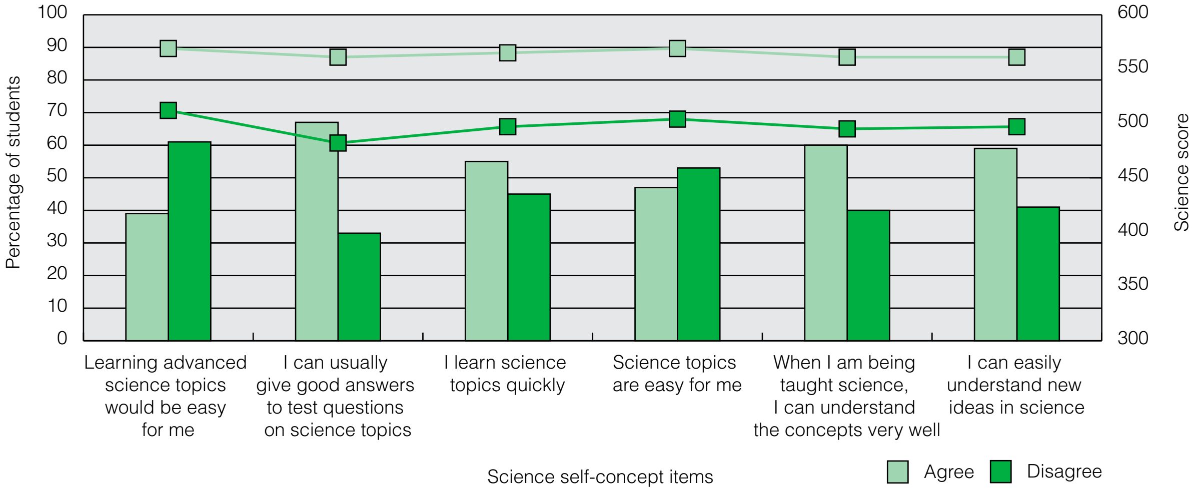


Figure 4.5 Australian student agreement to the science self-concept items

- Students were least confident of their ability to learn advanced science topics.
- The average scientific literacy score for students who agreed with the self-concept items was significantly higher than the Australian average scientific literacy score.
- In most countries, males had significantly higher levels of self-concept in science than females. In Australia, the level for males was significantly higher than the OECD average for males. For females, it was significantly lower than the OECD average for females.

Interest, engagement and motivation in science

Interest, motivation and engagement are important constructs in student learning. Interest in, and the enjoyment of, particular subjects relates to intrinsic motivation, which may influence whether students will be encouraged to work diligently and continue to learn in this area beyond school or pursue further educational opportunities in this field.

General interest in learning science

Eight items were used to measure how interested students are in learning science as a subject.

Students were asked to indicate their level of interest on a range of science topics on a four-point scale (high interest, medium interest, low interest and no interest). The science topics were:

- physics,
- chemistry,
- astronomy,
- geology,
- biology of plants,
- human biology,
- ways scientists design experiments, and
- what is required for scientific explanations.

An overall index of general interest in learning science was created using the data from these questions. Figure 4.6 shows the proportion of Australian students indicating high or medium interest in each of the science topics comprising this index.

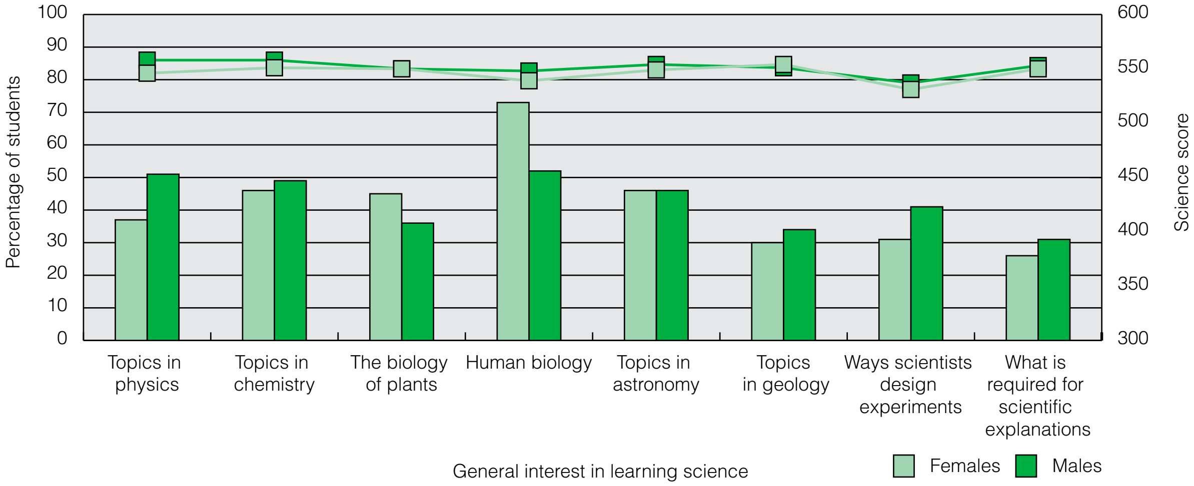
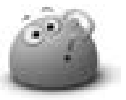


Figure 4.6 Australian student agreement to the general interest in learning science items, by gender

- Internationally, students from Colombia, Kyrgyzstan and Thailand reported the highest overall general interest in learning science, whereas students in the Netherlands, Finland, Korea and Australia showed the lowest general interest. The score on the index for Australian students was significantly lower than the OECD average. Clearly lack of interest is no handicap to performance, nor is interest a guarantee of high performance.
- There was no overall significant gender difference on this index in Australia but there are clearly differences in interest in particular topics. Male students indicated a higher level of interest than female students in topics in physics, chemistry and geology; whereas female students were significantly more interested in learning topics in biology.
- There was a moderate positive association between interest in science and performance in Australia. On average, there was a 73 score points difference between those students in the highest quarter of the general interest in learning science index and those in the lowest quarter – a little over two years of schooling.

What might be a reason for the high interest in science in the countries mentioned? On the other hand, why do you think that interest in learning science is lower in Australia, for example?



Enjoyment of science

Students were asked to think about their attitudes to science and learning science and indicate their agreement (strongly agree; agree; disagree; and strongly disagree) with the following statements:

- I generally have fun when I am learning science topics.
- I like reading about science.
- I am happy doing science problems.
- I enjoy acquiring new knowledge in science.
- I am interested in learning about science.

An enjoyment of science index was formed from students' responses to these items. Figure 4.7 shows the proportion of Australian students agreeing (either strongly agree or agree) with each of the statements on the enjoyment of science index.

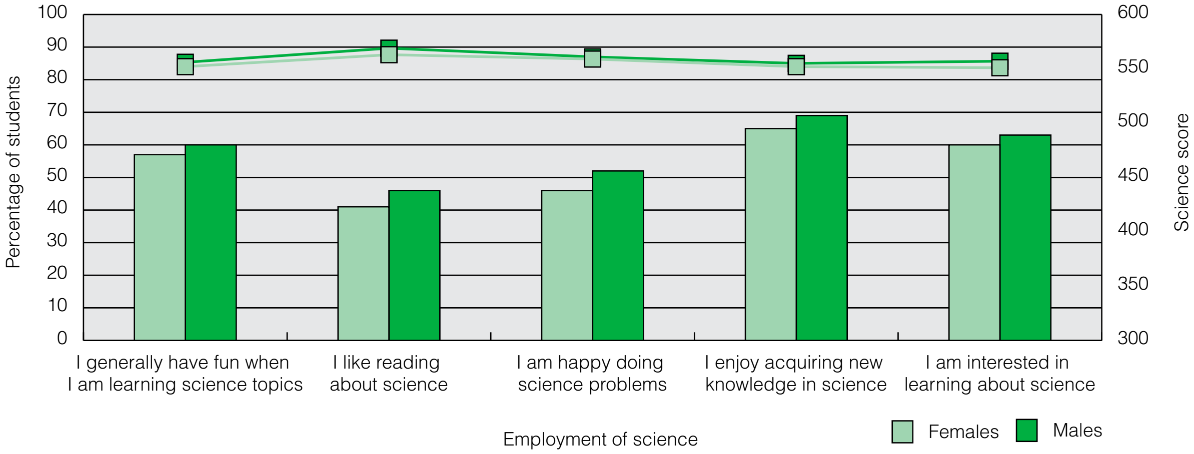
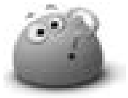


Figure 4.7 Australian student agreement to the enjoyment of science items, by gender

- Australian students' score on this index was slightly (but significantly) lower than the OECD average. This was the case for both males and females, with the index score for females being substantially lower than that of males.
- The relationship between enjoyment and achievement in science in Australia is reasonably strong – students in the highest quarter of the index score was, on average, 109 points higher than that of students in the lowest quarter. This is evident in Figure 4.7 – the students who agreed to the items were all in the high scoring range – over 550 score points.



Although it's good that almost 70 per cent of Australian students enjoy acquiring new knowledge in science, the reverse is that 30 per cent do not. Do you think this reflects the situation in your own class or school? What do you think can be done to improve this?

Instrumental motivation in science

PISA also assessed instrumental motivation in science. Instrumental motivation focuses on the external rewards that encourage students to learn, to choose subjects and to choose careers.

Five items were used to assess instrumental motivation. Students were asked how much they agreed or disagreed on a four-point scale (strongly agree; agree; disagree; and strongly disagree) with the following:

- Making an effort in my science subject(s) is worth it because this will help me in the work I want to do later on.
- What I learn in my science subject(s) is important for me because I need this for what I want to study later on.
- I study science because I know it is useful for me.
- Studying my science subject(s) is worthwhile for me because what I learn will improve my career prospects.
- I will learn many things in my science subject(s) that will help me get a job.

Figure 4.8 presents the proportion of Australian students agreeing (either strongly agree or agree) to the items comprising the instrumental motivation index.

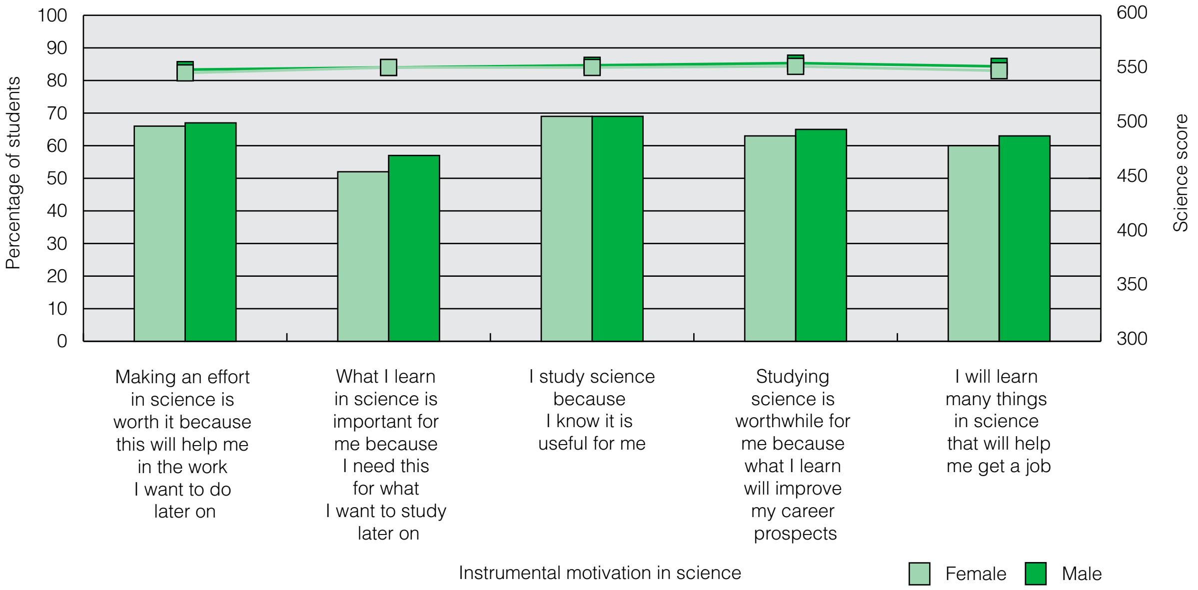


Figure 4.8 Australian student agreement to the instrumental motivation in science items, by gender

- Australia had a mean on the instrumental motivation index that was significantly higher than the OECD average, and there were no gender differences on this index.
- The majority of students responded positively to each of the items on this index. Although the differences are not large, male students still more often report that they are able to see the links between studying science and their future work or study.
- The relationship between instrumental motivation and scientific literacy for Australian students was moderately large, with students in the highest quarter of the index scoring, on average, 87 points higher than students in the lowest quarter of the index, the equivalent of almost three years of schooling.

Future-oriented motivation to learn science

Students´ expectations about studying science subjects beyond secondary school and working in science-related careers are another important aspect of student motivation to learn science, and they are also an important factor in countries´ ongoing and future scientific development.

Four items in the PISA 2006 Student Questionnaire assessed students´ motivation to take up a science-related career by asking students to indicate their level of agreement with the following (using a four-point scale: strongly agree; agree; disagree; and strongly disagree):

- I would like to work in a career involving science.
- I would like to study science after secondary school.
- I would like to spend my life doing advanced science.
- I would like to work on science projects as an adult.

Figure 4.9 presents the proportion of Australian students agreeing (either strongly agree or agree) to the items comprising the future oriented motivation index.

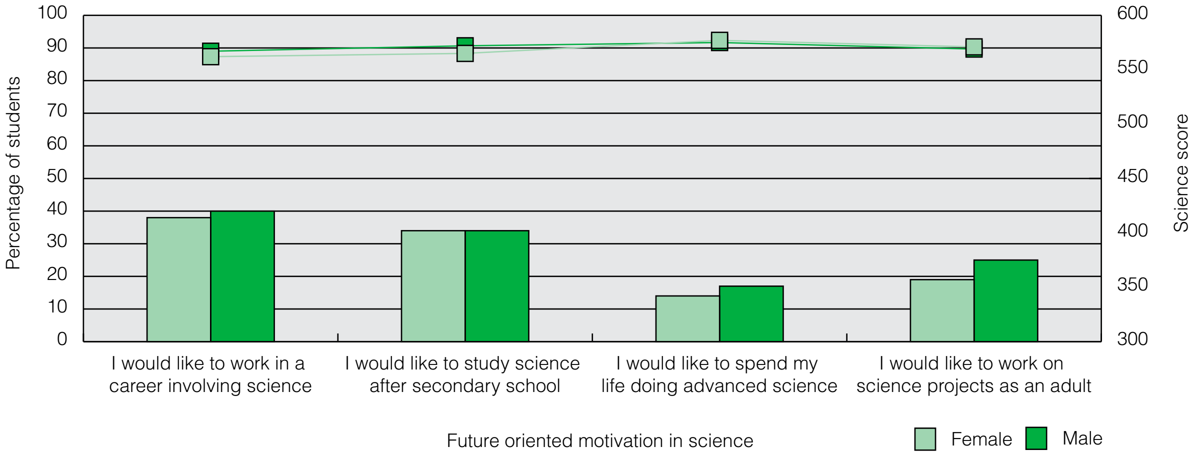


Figure 4.9 Australian student agreement to the future oriented motivation in science items, by gender

- Australia's mean on this index was slightly lower than the OECD average. There were significant gender differences in about 70 per cent of participating countries. Males from most countries had higher expectations about doing science studies at a tertiary level and working in a science-related career than females, reflecting current statistics about the actual proportion of women entering science, technology, engineering, mathematics (STEM)[5] courses at university.
- The average achievement level of the students who agreed that they did envisage a career in the sciences was very high. Whilst this may be appropriate for those students wishing to work in advanced sciences, and means that the sciences are attracting very high achieving students, there are many different types of science related careers that do not require students to be achieving at elite levels.

Fewer than 40 per cent of students reported that they were interested in a career involving science – do you think students have a good understanding of the range of careers that involve science in some way?

Responsibility towards resources and environments

PISA 2006 provided an opportunity to examine students´ opinions towards science learning. The skills and knowledge of 15-year-old students in scientific literacy equips them to assess environmental situations, to demonstrate a willingness to take action to maintain natural resources, and to show a sense of personal responsibility for maintaining a sustainable environment.

Responsibility for sustainable development

PISA collected information about students´ responsibility for sustainable development by asking students how much they agreed (using a four-point scale: strongly agree; agree; disagree; and strongly disagree) with the following statements:

- It is important to carry out regular checks on the emissions from cars as a condition of their use.
- It disturbs me when energy is wasted through the unnecessary use of electrical appliances.

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[5] Marginson, S., Tytler, R., Freeman, B. and Roberts, K. (2013). *STEM: Country comparisons. Report for the Australian Council of Learned Academies*, www.acola.org.au.

- I am in favour of having laws that regulate factory emissions even if this would increase the price of products.
- To reduce waste, the use of plastic packaging should be kept to a minimum.
- Industries should be required to prove that they safely dispose of dangerous waste materials.
- I am in favour of having laws that protect the habitats of endangered species.
- Electricity should be produced from renewable sources as much as possible, even if this increases the cost.

Figure 4.10 presents the proportion of Australian students agreeing (either strongly agree or agree) to the items comprising the responsibility for sustainable development index.

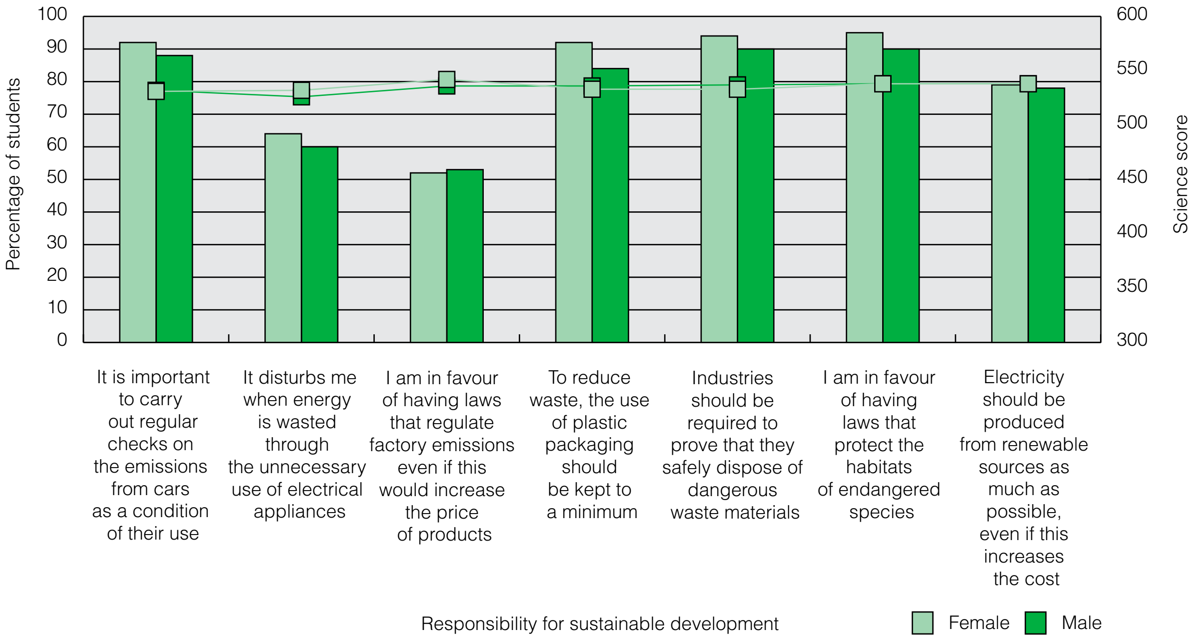
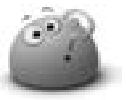


Figure 4.10 Australian student agreement to the responsibility for sustainable development items, by gender

- Australian students reported substantially lower levels on the sustainable development index than on average across the OECD. Seventy per cent of countries showed gender differences in favour of females, including Australia.
- Australian females were more likely than males to agree to the items on this scale.
- Students were less concerned about wasting energy through unnecessary use of appliances or of having laws to regulate factory emissions that resulted in an increase in prices.

Why do you think that 15 year-old students would care less about wasting electricity or enabling laws to regulate factory transmissions if it would increase prices?



Awareness of environmental issues

Awareness of environmental issues was assessed using five items in PISA 2006. Students were asked how informed they were about the following environmental issues:

- The increase of greenhouse gases in the atmosphere.
- Use of genetically modified organisms (GMO).
- Acid rain.
- Nuclear waste.
- The consequences of clearing forests for other land use.

Student responses were collected on a four-point scale with the categories: I have never heard of this; I have heard of this but I would not be able to explain what it is really about; I know something about this and could explain the general issue; and I am familiar with this and I would be able to explain this well.

The proportion of students in Australia who expressed some familiarity with each of the items is presented in Figure 4.11.

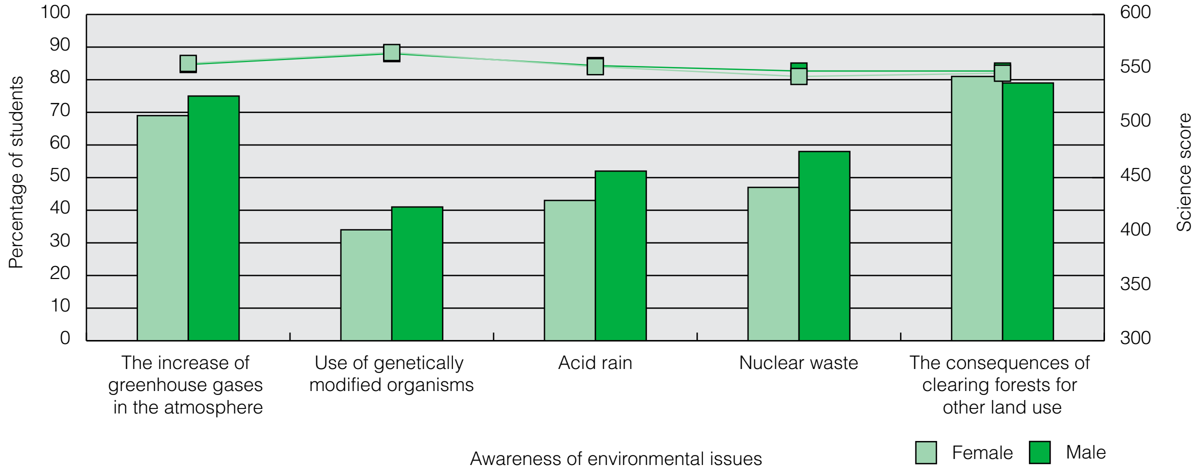


Figure 4.11 Proportion of Australian students who are somewhat familiar with environmental issues, by gender

- On average, Australia's score on this index was slightly higher than across the OECD, indicating Australian students are more aware of environmental issues than is the average.
- Clearly though, from Figure 4.11, this awareness is not consistent, with about three-quarters of students showing some familiarity with issues related to greenhouse gases and clearing forests. Curiously, less than half the respondents were familiar with issues relating to genetically modified organisms.
- Internationally, males reported higher levels of awareness of environmental issues than females in 70 per cent of countries. This was also the case in Australia, where males reported greater awareness of issues than females on all items other than forest clearing.

Why do you think males are more aware of environmental issues than females, given that females have more of a tendency towards being responsible for sustainable development?

Concern for environmental issues

Students were asked to indicate their perceptions of a range of environmental issues by marking one of four categories: this is a serious concern for me personally as well as others; this is a serious concern for other people in my country but not me personally; this is a serious concern for people in other countries; and this is not a serious concern to anyone. The environmental issues were:

- Air pollution.
- Energy shortages.
- Extinction of plants and animals.
- Clearing of forests for other land use.
- Water shortages.
- Nuclear waste.

The proportion of students in Australia who expressed concern either personally or for the country with each of the items is presented in Figure 4.12.

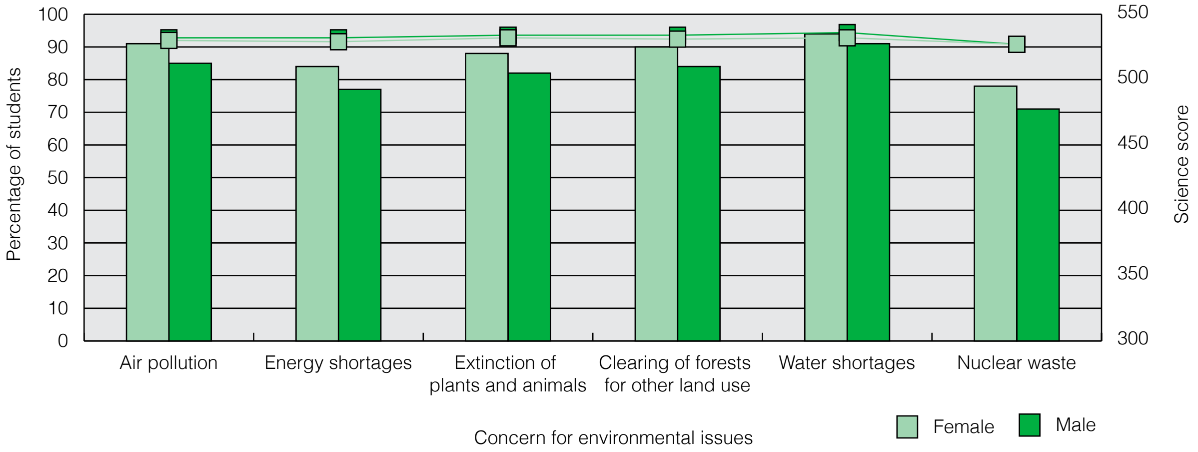


Figure 4.12 Proportion of Australian students who are somewhat concerned about environmental issues, by gender

- Australian students were less concerned about environmental issues than on average across the OECD.
- Over 90 per cent of countries reported that females were more concerned about environmental issues than males, and in Australia this was also the case, although both males and females were less concerned than the OECD average.
- Less concern was shown about nuclear waste than for any other topic.

Final Words

Australian students continue to perform at a high level compared to the rest of the world in scientific literacy. Australia's participation in international studies allows these comparisons to be made, and the national data allow patterns to be seen that are often not obvious at a local level.

Notable is Australia's lack of change in PISA scientific literacy scores since PISA 2006. The decline in mathematical literacy and reading literacy has been well documented, however this has not been the case for science. Rather than being complacent about this, it can be viewed as a solid basis from which to achieve even better scores.

Broadly, the proportions of students at the lower levels of achievement are strongly linked to socioeconomic opportunities. Thirty five per cent of our Indigenous students (compared to 12 per cent of non-Indigenous students) and 22 per cent of students from the lowest quartile of socioeconomic background (compared to four per cent from the highest quartile) are not achieving the basic level of scientific literacy (i.e. not achieving proficiency level 2). Are there particular strategies that can be used to scaffold the performance of these groups of students? What could be done to improve the learning and engagement with science of students from lower socioeconomic backgrounds?

Participation in the sciences in upper secondary school has been declining for a number of years, and the proportion of students entering courses in science, technology, engineering and mathematics (STEM) at tertiary level is concerning.[6] Some of the reasons for students not pursuing science past compulsory level may lie in the findings of the last chapter of this report.

The issue of gender differences in science achievement is an important one. While examining Australia's overall achievement score would indicate that there are no gender differences in science, a closer look reveals large gender differences in favour of males in physical systems and in Earth and space systems. There is much information in this report that can help teachers and schools to consider the way that science is taught in schools and the messages that young women receive.

The surveys of students provide some valuable information that may assist in improving outcomes for all students.

- The data from PISA shows that students who are interested in and enjoy science are more likely to be doing better at it than those who are not. Recognising the reciprocal relationship here, how do we engage students more with science so that they want to do it past the compulsory years?
- The data also show that enjoyment is not a necessary precursor to high achievement in science – understanding the role science plays in a students' future also plays a key role, and one that teachers and schools are able to assist with by explicitly relating students' learning to the real world.
- Teachers can support students' science learning by addressing issues of self-efficacy and self-concept.

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[6] Marginson, S, Tytler, R, Freeman, B and Roberts, K (2013). *STEM: Country comparisons* . Report for the Australian Council of Learned Academies, www.acola.org.au.

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