PISA 2006

Scientific Literacy

How ready are our 15-year-olds for tomorrow's world?

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Te Tāhuhu o te Mātauranga Aotearoa

OECD PISA
Programme for International Student Achievement

An Overview of PISA

What is PISA?

The Programme for International Student Assessment (PISA) is an international standardised study that assesses and compares how well countries are preparing their 15-year-old[1] students to meet real-life opportunities and challenges.

What does PISA assess?

PISA assesses three key areas of knowledge and skills – reading literacy, mathematical literacy and scientific literacy – and has a focus on one of these literacy areas each time PISA is administered. The focus of PISA 2006 is science. The term 'literacy' is used to emphasise that the assessment is not restricted to assessing how well students have mastered the content of a specific school curriculum. Instead, PISA focuses on assessing students' ability to apply their knowledge and skills, and their ability to make decisions in real-life situations. PISA defines this approach as assessing the "*knowledge, skills, competencies and other attributes embodied in individuals that are relevant to personal, social and economic well-being*" (OECD 2006, p. 11).

What additional information is gathered?

Background information is also gained in each PISA cycle from questionnaires completed by students and school principals. In addition, in PISA 2006 parents completed a questionnaire. These questionnaires allow for the relationship between contextual information and achievement to be examined.

How often is PISA administered?

PISA is administered every three years, beginning in 2000. Reading was the main focus in the first cycle. In 2003 the focus was mathematical literacy, and in 2009 it will be reading literacy again. Rotating the main focus for each administration of PISA provides in-depth and detailed information on the subject of main focus along with an ongoing source of achievement data on the two minor subjects.

Who participates in PISA?

Around 400,000 15-year-old students from 57[2] countries, including the 30 Organisation for Economic Co-operation and Development (OECD) member countries, participated in PISA 2006. In New Zealand 4,824 students from 170 schools took part. Students and schools were randomly selected. A two-tiered stratified sampling method was used to ensure the sample was representative. Students were sampled from schools of different sizes, school authority and decile groupings, and from urban and rural schools. As a result, every 15-year-old had roughly the same chance of selection (see Appendix 1).

Why participate in PISA?

PISA assesses students who have completed around 10 years of compulsory schooling, which means the PISA results are an important source of information in New Zealand. PISA measures progress towards the Government's goals of:

- building an education system that equips New Zealanders with 21st century skills, and
- reducing systemic underachievement in education.

PISA not only allows measurement of New Zealand's progress on these goals over time, but also allows measurement of New Zealand's performance relative to other countries in equipping students with skills and reducing disparities in achievement. The PISA data provide evidence to inform policy and practice in literacy, numeracy and curriculum development.

Who organises PISA?

PISA is an initiative of the OECD and a collaborative effort of the participating countries. A consortium is responsible for developing and overseeing PISA 2006 at the international level. This consortium is led by the Australian Council for Educational Research (ACER), and consists of the Netherlands National Institute for Educational Measurement (Citogroup), Westat (USA), the Educational Testing Service (ETS, USA), and the Japanese National Institute for Educational Policy Research (NIER, Japan). In New Zealand, the Comparative Education Research Unit within the Ministry of Education's Research Division is responsible for PISA.

How did countries ensure the PISA data were of high quality?

A number of quality assurance procedures were put in place, both nationally and internationally, to ensure the data were as high a quality as possible. These included: rigorous training of staff; high-quality documentation; monitoring of sampling procedures; quality checks and monitoring at a number of stages, including during administration of the tests; multiple coding and data entry procedures; and data cleaning and checking procedures. Further details of international procedures can be found in Appendix 7 and the PISA 2006 Technical Report (OECD 2009b).

1 Students are aged between 15 years 3 months and 16 years 2 months. Most students are aged 15, so here they are referred to as '15-year-olds' for brevity.

2 The countries participating in PISA 2006 are listed on the back cover.

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Key findings

All students

- The mean score of New Zealand's 15-year-old students in PISA 2006 was well above the OECD mean. Only two countries had a significantly higher score.
- New Zealand and Finland had the largest proportion of students at the top proficiency levels. At the same time New Zealand had a large proportion at the lowest levels relative to other high performing countries. As a result, New Zealand had one of the widest ranges of science scores of any OECD country.
- More than ninety percent of students were in schools where there were top science performers.
- New Zealand students performed extremely well on identifying scientific issues and using scientific evidence. They were less strong on explaining phenomena scientifically.
- New Zealand students performed strongly on living systems and earth and space systems but were relatively weak on physical systems. They achieved high scores on the knowledge about science scale.
- New Zealand students were similar to, or slightly above, the OECD mean in terms of interest, enjoyment and motivation. They were below the OECD mean in terms of confidence in learning and understanding science.

Gender

- In terms of overall scientific literacy, there was no significant difference between boys and girls in New Zealand, although boys were slightly more likely to be at the top or bottom of the scale.
- On identifying scientific issues, New Zealand girls obtained significantly higher scores; boys were stronger on earth and space systems and physical systems.
- New Zealand boys enjoyed science more than girls and had greater confidence in their own ability.

Ethnicity

- Pākehā/European students obtained the highest scores, followed by Asian, Māori and Pasifika students, in that order.
- The proportion of Asian students reaching the highest proficiency levels was similar to that for Pākehā/European students, but there was a higher proportion of Asian students at the lowest levels than Pākehā/European.
- Asian students had consistently the most positive views on engagement with science.

Family background

- There was a strong relationship between science achievement and students' socio-economic background. This relationship was stronger in New Zealand than in most OECD countries.
- Students from single-parent families in 2006 performed less well overall than students from other family types. However, students from single-parent families at 15 were more likely to come from families with a low socio-economic background, and after taking socio-economic factors into account there was no difference in performance compared to students from other family types.

- Students born overseas with parents also born outside New Zealand (first-generation immigrants) performed almost as well as students with a New Zealand-born parent ('native'). However, New Zealand-born students with parents born overseas (second-generation immigrants) performed significantly weaker overall.
- Other factors linked with high science literacy achievement included a high level of parental education, speaking English at home and having access to educational resources. Students who had changed school frequently were likely to perform less well.
- Students from high socio-economic backgrounds had more positive views on engagement with science.

School context

- Students from large, urban and high-decile schools tended to have higher scores, as did students from schools where resourcing was considered to be good. Students from schools where principals reported science teacher shortages hindered instruction tended to have lower scores.
- Within New Zealand schools the scientific literacy ability of students was very diverse. The variation in student performance within schools was the largest of all PISA countries, but the variation between our schools was significantly smaller than the OECD average.
- Most New Zealand PISA students were in Year 11, but there were some in Year 10 or Year 12. The higher the year group, the higher the average score obtained.
- Ninety percent of the PISA students were taking a compulsory and/or optional science course; their average score was much higher than those who were not. Māori students were less likely than any other ethnic grouping to take science courses.
- The strongest relationship measured was between science literacy scores and educational aspirations. Those with a positive attitude to school in general, and science in particular, achieved higher scores than those who indicated a degree of disaffection.

Introduction

Introduction

The Programme for International Student Assessment (PISA), an initiative of the Organisation for Economic Co-operation and Development (OECD), assesses three key areas of knowledge and skills: reading literacy, mathematical literacy and scientific literacy. It is administered every three years, and each survey assesses one subject in more detail. In 2006 the main focus was scientific literacy.

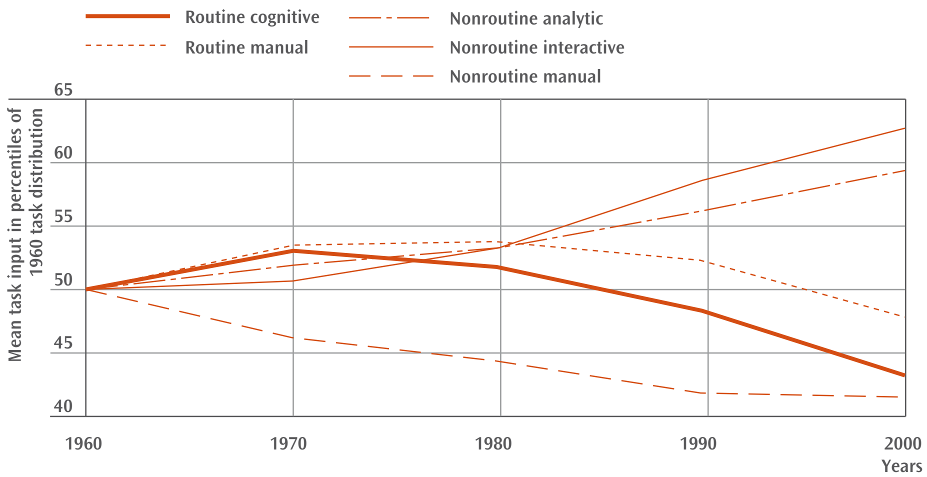
New Zealand has participated in PISA since the study began in 2000. The number of countries taking part in PISA continues to grow, with 32 countries in 2000, 41 countries in 2003 and 57 countries in this administration of PISA, including the 30 OECD member countries. Please refer to 'An overview of PISA' (inside cover of this report) for more information[3].

3 See also Turner, R. & Adams and OECD 2007a.

Background

PISA is designed to measure students' preparedness for the 21st century, with a focus on students' ability to *apply* their knowledge and skills to meet real-life challenges. A study of the United States labour market between 1960 and 2000[4] supports this approach, and highlights how students might not be prepared with the skill set necessary for the 21st century if their learning is limited to memorising and reproducing knowledge acquired from a specific curriculum. As can be seen in Figure 1, the demand for routine cognitive skills has declined even more sharply than the demand for routine manual skills. Jobs that require non-routine interactive skills (*complex communication skills)* and non-routine analytic skills (*expert thinking and problem-solving skills*) are increasingly in demand, and many of these types of skill sets are assessed in PISA.

Figure 1: How skill demands in the job market have changed – trends in routine and non-routine task input in the United States since 1960



Source: Autor et al., 2003; Levy and Murnane 2006

Note: Data are aggregated to 1 120 industry-gender-education cells by year and each cell is assigned a value corresponding to its rank in the 1960 distribution of task input (calculated across the 1 120 task cells for 1960). Plotted values depict the employment-weighted mean of each assigned percentile in the indicated year.

Source: OECD 2007a, p. 33.

The New Zealand Department of Labour (2008) has also identified how the types of skills required in New Zealand's labour market are changing as jobs become more knowledge-intensive and communication skills and attitudes become increasingly important. New Zealand's science curriculum emphasises the application of knowledge and skills in real-life settings, rather than limiting science teaching and learning to the foundational knowledge required for the professional training of scientists.

4 Cited in: OECD 2007a, p. 33.

The aim of PISA 2006 was to assess the scientific literacy knowledge and skills of 15-year-olds who had completed around 10 years of compulsory schooling. The increasingly important role of science in 21st century life means that all adults – not only those aspiring to a career in science – need to be scientifically literate. An understanding of science is needed in order to function effectively in daily life, to make judgements, and to take appropriate action regarding many of the issues and problems that arise at the personal, local, national and global levels. Young people therefore need an understanding of science in order to be fully prepared for life in modern society.

PISA reporting for New Zealand

This report forms part of a series presenting an analysis of the PISA 2006 results for New Zealand students. First was a summary report, looking at the New Zealand findings in all three key subject areas (Telford and Caygill 2007). Reflecting the main concern of PISA, as outlined above, it bears the title *How ready are our 15-year-olds for tomorrow's world?* There are also reports dealing specifically with mathematical literacy (Caygill et al. 2008) and reading literacy (Marshall et al. 2008), which were the minor focuses of PISA 2006. Two other reports provide background to the science focus: one looks at the school context of science achievement (Caygill & Sok 2008) and the other at student attitudes to and engagement with science (Caygill 2008a).

The present report, the final in the series, provides a more detailed account of the PISA 2006 New Zealand findings relating to science. It explores questions such as:

- How scientifically literate are young people in New Zealand compared with those in other countries?
- In which aspects of science are they particularly strong, or weak?
- How do groups of young people differ in terms of their achievements in science?
- What factors might help to explain the New Zealand findings?

The purpose of the report is to provide an introduction to the rich source of data available from PISA 2006. It indicates the overall levels of science literacy among New Zealand students, measured by international standards. In addition, the background information obtained from participants makes it possible to analyse the strengths and weaknesses of different groups of students in particular areas of scientific knowledge. There is also a wealth of information about students' attitudes to science and their awareness of environmental issues.[5] Inevitably the PISA findings do not answer all the questions that New Zealand education stakeholders may wish to ask; for example, they identify differences, but cannot always explain the reason(s) why those differences exist. Perhaps their greatest value is in raising issues that require thought and further exploration.

Following this brief introduction the report is divided into six chapters. The second chapter looks at how New Zealand students compare with others on the PISA index of scientific literacy, on various aspects of science, and in terms of attitudes to science and awareness of environmental issues. The next four chapters consider differences between identified groups of young people in New Zealand, looking particularly at gender (third chapter), ethnicity (fourth chapter), family background (fifth chapter) and school context (sixth chapter). The final chapter summarises the findings and suggests questions for schools and policymakers to address.

At the end of the report seven appendices describe in detail various aspects of PISA 2006: how the student sample was drawn; the structure of the PISA scientific literacy framework; the design of the PISA questions and test booklets; examples of questions and scoring methods; the PISA proficiency levels; a description of the 'student attitude' indices; and quality assurance.

5 See Green at fifteen? How 15-year-olds perform in environmental science and geoscience in PISA 2006 (OECD 2009d).

New Zealand students and science

In this chapter we present science findings for New Zealand students in comparison with those from other OECD and partner countries.[6] We look first at the PISA index of scientific literacy,[7] then at scores for different aspects of science (competencies and knowledge domains), and finally we make brief reference to student attitudes to science. Some of the material has been covered elsewhere (Telford & Caygill 2007; Caygill 2008a), and reference will be made to these reports as appropriate.

Scientific literacy

To provide a high-level picture of achievement, PISA constructs a literacy scale for each of the three key literacy areas. The combined *scientific literacy scale* summarises the results from the three science sub-scales: *knowledge of science*, *knowledge about science* and *scientific literacy competencies*.

New Zealand students were among the best in the world in terms of scientific literacy. Scores were constructed around a mean of 500 points for the 30 OECD countries participating in PISA 2006. About two-thirds of the students across OECD countries scored between 400 and 600 points. New Zealand students had a mean score of 530, well above the OECD average.

Of the 57 countries participating in PISA 2006, only Finland (with an average of 563 points) and Hong Kong-China* (542) scored significantly above New Zealand. Eight other countries had scores that were statistically similar to New Zealand: Canada (534), Chinese Taipei* (532), Estonia* (531), Japan (531), Australia (527), the Netherlands (525), Liechtenstein* (522) and Korea (522).[8] In this chapter we quote, where relevant, comparisons with the countries just mentioned (referred to as the 'top-performing countries'), and also with the United Kingdom (515) and the United States (489): their results, although significantly lower than New Zealand's, are of interest because they are both large English-speaking countries.

Science trend information

This is the first time science has been the main focus of PISA. Science trend information in future cycles will be based on the assessment developed for this cycle. However, on the science questions administered in both 2003 and 2006 there was no change in New Zealand's performance. Only three OECD countries showed a change (Mexico, +22.7 score points; Greece, +20.5 score points; and France, –16.2 score points).

6 Partner countries are non-OECD countries that participated in PISA 2006. They are denoted with an asterisk in this report.

7 See Appendix 2 for details of the PISA scientific literacy framework. For a full description, see OECD 2006.

8 Chinese Taipei* and Estonia* participated in PISA for the first time in 2006.

Table 1: Mean scores for 5th and 95th percentile groups of OECD countries

OECD countries	Science 5th percentile score	Standard error	Range between the 5th and 95th percentile	OECD countries	Science 95th percentile score	Standard error
Finland	419	(4.4)	281	*Finland*	700	(3.1)
Canada	372	(4.7)	309	***New Zealand***	699	(3.1)
Korea	367	(8.4)	295	United Kingdom	685	(3.5)
Netherlands	362	(5.9)	313	*Australia*	685	(3.4)
Hungary	358	(4.4)	288	*Japan*	685	(3.6)
Australia	358	(3.5)	327	*Canada*	681	(2.8)
Japan	356	(6.1)	329	*Netherlands*	675	(3.6)
Poland	352	(3.8)	293	Germany	672	(3.6)
Ireland	351	(5.8)	309	Czech Republic	672	(4.7)
Czech Republic	350	(6.0)	322	Switzerland	665	(4.6)
New Zealand	347	(5.2)	**352**	Austria	663	(4.1)
Sweden	347	(3.8)	307	*Korea*	662	(5.9)
Germany	345	(8.1)	327	United States	662	(4.8)
Austria	341	(9.3)	322	Ireland	660	(4.9)
Denmark	341	(5.9)	305	Belgium	660	(2.7)
Switzerland	340	(5.0)	325	Sweden	654	(3.4)
OECD	340	(1.0)	312	OECD	652	(0.8)
Spain	338	(4.1)	295	France	653	(3.8)
United Kingdom	337	(5.4)	348	Hungary	646	(4.2)
Belgium	336	(7.3)	324	Denmark	646	(4.3)
Slovak Republic	334	(5.6)	304	Poland	645	(3.3)
Portugal	329	(5.4)	288	Iceland	644	(3.4)
Norway	328	(7.8)	313	Norway	641	(3.4)
Iceland	328	(4.9)	316	Luxembourg	640	(2.6)
Luxembourg	322	(3.9)	318	Slovak Republic	638	(3.9)
France	320	(6.3)	333	Spain	633	(3.1)
United States	318	(4.5)	344	Italy	630	(2.8)
Italy	318	(3.1)	312	Greece	619	(3.8)
Greece	317	(7.3)	302	Portugal	617	(3.2)
Turkey	301	(2.8)	274	Turkey	575	(9.8)
Mexico	281	(4.4)	263	Mexico	544	(3.5)

Source: OECD 2007b, Table 2.1c, p. 28.

Note: Top-performing countries (those with scores significantly higher than New Zealand's or statistically similar to New Zealand's) are shown in italics.

Distribution of student scores

In addition to looking at the mean scores for each country, it is helpful to look at the distribution of scores. To take an extreme example, two countries might have the same average score, but in one case all students might have scores close to the mean, while in the other case half might have very high scores and the other half very low. The range of student achievement is represented by the difference between the lowest five percent and the highest five percent of participating students. Countries with a relatively small range are considered to have an equitable education system.

As can be seen in Table 1, New Zealand's and Finland's top five percent of 15-year-olds achieved the highest science mean score of all the OECD countries: a score that was close to 50 points higher than the OECD average for the 95th percentile. The top five percent of students in New Zealand thus performed as well as the top five percent in Finland, and better than the top five percent in any other OECD country.

At the lower end of the scale, however, the picture was different. In Finland, five percent had a score below 419, while in New Zealand five percent had a score below 347. Hence the range of science scores was much broader in New Zealand (352) than in Finland (281). Indeed, New Zealand had one of the widest ranges of any OECD country, along with the United Kingdom (348) and the United States (344).

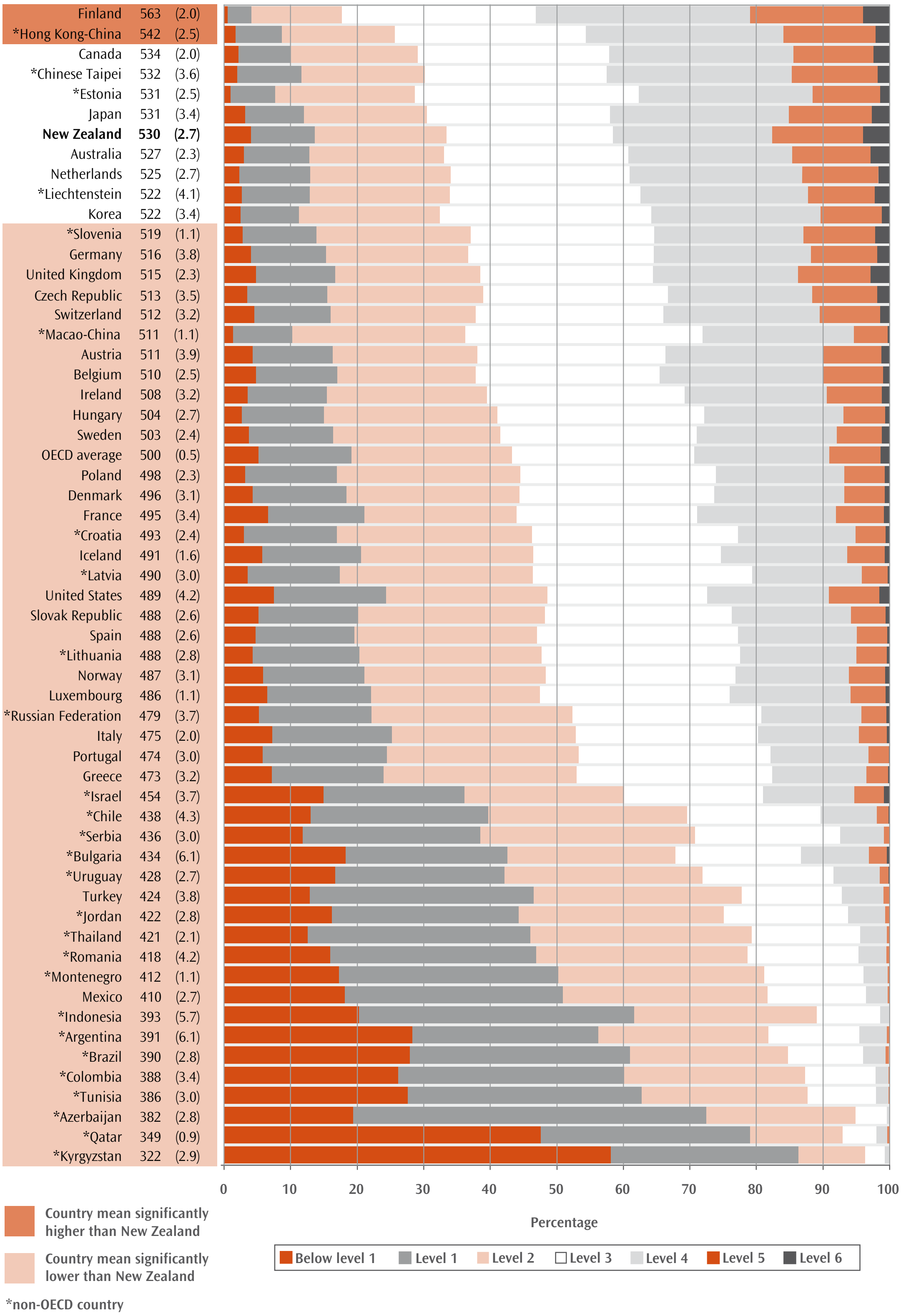
Proficiency levels on the scientific literacy scale

The PISA proficiency levels (described in Appendix 5) provide rich and robust data on the spread of student achievement and at the same time describe the types of task that students achieving a particular level could typically be expected to complete.

Figure 2 shows the percentage of students achieving each of the six proficiency levels in all of the PISA 2006 countries. New Zealand (4.0%) and Finland (3.9%) had the largest proportion of students demonstrating the highest level of scientific proficiency (Level 6). Close to one in five of New Zealand students (17.6%) were proficient at Level 5 or higher; only Finland (20.9%) had a greater proportion in this category.

Around half of Finland's (53.2%) and Hong Kong-China's* (45.6%) 15-year-olds demonstrated proficiency at Level 4 or higher. Among New Zealand students the proportion was 41.5%, similar to Chinese Taipei* (42.5%), Canada (42.1%), Japan (42.0%), Australia (39.2%) and the Netherlands (39.0%).

Figure 2: Percentage of students at each of the six proficiency levels



Source: OECD 2007b, Tables 2.1a, p. 24; and 2.1c, p. 27.

One-third (33.4%) of New Zealand's 15-year-olds did not demonstrate competency beyond Level 2, a proportion that was similar to that of four of the other top-performing countries (Australia, Korea, Liechtenstein* and the Netherlands). A smaller proportion of students from the remaining top-performing countries were at these lower levels.

In New Zealand, 13.7% of students did not achieve beyond Level 1 and 4.0% did not achieve even Level 1. Among the other top-performing countries, the proportion of students at these levels was similar or smaller; Finland had the smallest proportion, with 4.1% not reaching Level 2 and only 0.5% not achieving Level 1. However, in the United States the proportions were significantly higher than in New Zealand (24.4% at Level 1 or below, 7.6% not reaching Level 1), and in the United Kingdom (16.7% at Level 1 or below, 4.8% not reaching Level 1) they were also higher than New Zealand.

As can be seen from the figures just quoted, New Zealand had a relatively high proportion of students at both ends of the scientific literacy scale. In order to measure and compare the variation in student performance for each country, the OECD mean variation (variance[9]) was set at 100 percent. Countries with a value of more than 100 percent had a variation in student science performance greater than the average for all OECD countries, while countries with a value of less than 100 percent had a smaller variation. At 125.2%, New Zealand, along with the United States (124.7%) and the United Kingdom (124.4%), had the largest variation in student performance of all OECD countries. Not surprisingly (given the small proportion of students at the lower levels), Finland had the smallest variation in student performance among the 30 OECD countries (81.4%). Finland has consistently achieved a very high result on the three PISA literacy areas over the last three administrations.

Scientific competencies

As explained in Appendix 2, PISA test questions were designed to assess three scientific competencies:

- **identifying scientific issues** – recognising issues that are possible to investigate scientifically, the key features of a scientific investigation, and identifying keywords to search for scientific information.
- **using scientific evidence** – interpreting scientific evidence and making and communicating conclusions; identifying the assumptions, evidence and reasoning behind conclusions; and reflecting on the societal implications of science and technological developments.
- **explaining phenomena scientifically** – applying knowledge of science in a given situation; describing or interpreting phenomena scientifically and predicting changes; and identifying appropriate descriptions, explanations and predictions.

Scores for individual students, and means for countries and for the OECD, were calculated for each of these. As can be seen in Table 2, New Zealand students scored well above the average on all three competencies. They were particularly strong on identifying scientific issues and using scientific evidence. Finland was the only country to achieve significantly higher scores on these two competencies, although the performance of most other top-performing countries was statistically similar to New Zealand's.

Identifying scientific issues

Of all OECD countries, New Zealand had the highest proportion of students achieving Level 6 (4.3%) or at least Level 5 (18.5%), even higher than Finland (2.6% and 17.2% respectively). Across the OECD countries, on average only 8.4 percent of 15-year-olds achieved these upper levels.

At the other end of the scale, one in eight New Zealand students (12.3%) were at Level 1 or below. This was much higher than Finland (4.9%), but similar to Australia, Canada, Korea and the Netherlands, and below Japan, United Kingdom, the United States and the OECD mean (18.7%).

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9 See Definitions and Technical Notes p. 80 .

Table 2: Mean scores on the scientific literacy competencies

Top-performing countries and the United Kingdom and United States	Identifying scientific issues		Using scientific evidence		Explaining phenomena scientifically	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Australia	535	(2.3)	531	(2.4)	520	(2.3)
Canada	532	(2.3)	542	(2.2)	531	(2.1)
Finland	555	(2.3)	567	(2.3)	566	(2.0)
Japan	522	(4.0)	544	(4.2)	527	(3.1)
Korea	519	(3.7)	538	(3.7)	512	(3.3)
Netherlands	533	(3.3)	526	(3.3)	522	(2.7)
United Kingdom	514	(2.3)	514	(2.5)	517	(2.3)
United States	492	(3.8)	489	(5.0)	486	(4.3)
Chinese Taipei*	509	(3.7)	532	(3.7)	545	(3.7)
Estonia*	516	(2.6)	531	(2.7)	541	(2.6)
Hong Kong-China*	528	(3.2)	542	(2.7)	549	(2.5)
Liechtenstein*	522	(3.7)	535	(4.3)	516	(4.1)

Source: OECD 2007b, Tables 2.2c, p. 32; 2.4c, p. 42; and 2.3c, p. 37.

*Note: *denotes non-OECD countries.*

Using scientific evidence

At the higher levels, the performance of New Zealand students (6.9% Level 6, 22.4% at least Level 5) was similar to that of Finland (6.7% and 25.0% respectively), Japan (6.2% and 22.9%) and Liechtenstein (5.3% and 20.7%). Other top-performing countries had smaller proportions of students at these levels, as did the United Kingdom and the United States. The proportion achieving at least Level 5 in New Zealand was almost double the OECD average (11.8%).

The proportion of New Zealand students not demonstrating proficiency above Level 1 was 15.4%. This was higher than Finland, Australia and Canada, but lower than the United Kingdom, the United States and the OECD average.

Explaining phenomena scientifically

On this competency New Zealand students performed less strongly, although still well above the OECD average. Level 6 was achieved by 4.2% of New Zealand students (equal to Chinese Taipei*, and second to Finland with 5.1%). One in six (16.4%) of New Zealand students achieved at least Level 5, a significantly smaller proportion than Finland (22.6%) and Hong Kong-China* (18.9%), but higher than five of the high performing countries.

The proportion of New Zealand students not demonstrating proficiency above Level 1 was 16.1%. This was higher than the other high performing countries, but lower than the United States and the OECD average.

Scientific knowledge domains

As explained in Appendix 3, PISA test questions were also designed to assess knowledge *of* science and knowledge *about* science. The knowledge *of* science domain assessed science content knowledge in four areas:

- physical systems
- living systems
- earth and space systems
- technology systems[10]

Knowledge of science

The first three content areas (which fall broadly into the science strands of the New Zealand Curriculum (see Appendix Table A2.3) were reported separately, and on all measures New Zealand students were well above the OECD mean. An overall knowledge *of* science scale, which summarised student results on the four content areas, was also created, and New Zealand's 15-year-olds' average score on this measure was 524 – statistically similar to five of the other top-performing countries (including Australia), but significantly lower than the remaining five.

Of the three PISA science content areas reported separately, New Zealand students performed strongly on *living systems* and *earth and space systems*, with only four countries out-performing New Zealand on the former and three on the latter. A relatively weaker mean performance was observed on the content area *physical systems*.

Table 3: Mean scores on the science content areas

Top-performing countries and the United Kingdom and United States	Living systems		Earth and space systems		Physical systems	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Australia	522	(2.1)	530	(1.9)	515	(1.9)
Canada	530	(2.1)	540	(1.8)	529	(1.9)
Finland	574	(1.8)	554	(1.8)	560	(1.7)
Japan	526	(2.7)	530	(3.0)	530	(3.2)
Korea	498	(2.8)	533	(3.0)	530	(3.0)
Netherlands	509	(2.4)	518	(2.7)	531	(2.5)
United Kingdom	525	(2.2)	505	(1.9)	508	(2.0)
United States	487	(4.1)	504	(4.0)	485	(3.8)
Chinese Taipei*	549	(3.3)	529	(3.0)	545	(3.1)
Estonia*	540	(2.4)	540	(2.4)	535	(2.0)
Hong Kong-China*	558	(2.3)	525	(2.4)	546	(2.4)
Liechtenstein*	524	(4.4)	513	(4.8)	515	(4.1)

Source: OECD 2007b, Tables 2.8, p. 48; 2.9, p. 50; and 2.10, p. 52.

*Note: *denotes non-OECD countries.*

It is interesting to compare the PISA findings on science content knowledge with those of the Trends in International Mathematics and Science Study (TIMSS), which was administered in 2006 to Year 5 New Zealand students, most of

10 There were insufficient questions for technology systems to allow for analysis at an individual content level. These items were included in the overall knowledge of science scale.

whom were 10 years old.[11] While it is important to bear in mind that the conceptual frameworks for PISA and TIMSS differ, TIMSS assessed students on three content areas similar to those assessed in PISA: 'life science' (*living systems*), 'earth science' (*earth and space systems*) and 'physical science' (*physical systems*).

A similar pattern of scientific performance was observed for New Zealand's TIMSS and PISA students. In TIMSS, Year 5 students' highest scores were for 'earth science' and their lowest for 'physical science' (Caygill 2008b). However, while PISA's 15-year-olds performed strongly on *living systems*, Year 5 students in TIMSS performed less well on the 'life science' content area compared to their performance on the 'earth science' scale.

Knowledge about science

The knowledge *about* science domain assessed students' knowledge of scientific enquiry and scientific explanations. New Zealand students performed strongly on this scale, achieving an average score of 539. Only Finland (558) achieved a significantly higher mean score, although the mean performance of five other top-performing countries (including Canada and Australia) was statistically similar.

Attitudes to science

As part of assessing scientific literacy in PISA 2006, students responded to questions on engagement and motivation and their attitudes to scientific issues (please see Appendix 6 for these indices and the questions from which they are derived). Detailed findings have been reported separately (Caygill 2008a) but are summarised briefly here to complete the picture of New Zealand students.

Interest, enjoyment and motivation

Students were questioned about their interest in scientific topics, their enjoyment of science in general, how useful they considered school science to be, and the likelihood of their future involvement in science. The proportion of New Zealand students indicating high or medium interest in a range of scientific topics was similar to the OECD average. Levels of enjoyment of science were also similar, although New Zealand students were less likely to enjoy reading about science and more likely to enjoy doing science problems.

Relatively few New Zealand students engaged regularly in science-related activities in their leisure time. In this respect New Zealand was below the OECD mean but comparable with Finland, Australia and the United Kingdom. New Zealand students were above the OECD average in terms of instrumental motivation (believing that science learning would be generally useful, and would improve career prospects), and equal to the OECD average in future-oriented motivation (wanting to engage in science-related work or study after school).

The value of school science

New Zealand students were slightly more likely than the OECD average to agree with most statements about the value of current science learning; in particular, two-thirds (66% compared with the OECD mean 56%) believed they would learn many things in science that would help them get a job. Compared with the OECD average, New Zealand students were less likely to want to work on science projects as adults, or to spend their lives doing advanced science, but more likely to want to study science after secondary school and to work in a career involving science. In New Zealand (24%) and across the OECD countries (25%), a quarter of the students surveyed expected to have a science-related career at age 30.

Self-concept and self-efficacy

On most issues relating to self-concept (how good they believe they are at science) and self-efficacy (the ease with which they anticipate completing scientific tasks), New Zealand students gave responses close to the OECD average. However, they were less likely to say that learning advanced science topics would be easy (40%, compared to the OECD mean of 47%) and less confident about identifying the correct explanation for the formation of acid rain (48%, compared with the OECD mean of 58%).

11 To minimise the burden on New Zealand secondary schools, Year 9 students did not take part in the TIMSS 2006/07 cycle.

The general value of science

New Zealand students generally agreed with those in other OECD countries about the general value of science; interestingly, however, they were more likely to believe that advances in science usually improve the economy (86%) and less likely to believe that such advances usually bring social benefits (66%). On a personal level, two-thirds believed that after leaving school they would have many opportunities to use science (65%, compared with the OECD mean of 57%).

Awareness of environmental issues

New Zealand students differed markedly from the OECD mean in terms of their awareness of, and concern about, environmental issues. Almost half (48%, compared to the OECD mean of 35%) knew at least something about the use of genetically modified (GM) organisms and could explain the issue to others. However, on acid rain (44%) and nuclear waste (40%) New Zealand students were well below the OECD mean (60% and 53% respectively). Similarly, the proportion of New Zealand students believing air pollution and nuclear waste to be serious concerns (82% and 60% respectively) was lower than the OECD average (92% and 78%).

Solving environmental problems

With regard to solving environmental problems, New Zealand students were among the least optimistic of the countries surveyed. They were also below the OECD average in terms of taking responsibility for sustainable development. While on most issues their views were close to the OECD mean, fewer were concerned about wasting energy through unnecessary use of electrical appliances (58%) and in favour of laws regulating factory emissions (49%); the OECD average for both of these items was 69 percent.

Attitudes to science and scientific literacy achievement

When looking at the relationship between attitudes to science and scientific literacy performance, there was a positive relationship between students' interest in science and their science literacy achievement in New Zealand and on average across the OECD. This is not surprising, but it is interesting to note that it was not the case in every country. For example, Korea, Finland and the Netherlands, each with a large proportion of high-performing students, were among the countries with the smallest proportion of students reporting high or medium levels of interest in science topics.

There were also clear positive relationships between achievement and:

- enjoyment of science (this was particularly strong in New Zealand, and also in Australia and the United Kingdom)
- motivation (instrumental and future-oriented)
- students' belief in their own science abilities (self-concept and self-efficacy)
- participation in science-related leisure-time activities
- belief in the value of science (general and personal)
- awareness of environmental issues

These are all as might be expected, but should not be understood to imply causality in either direction. For example, it may be that greater participation in out-of-school-hours science activities leads to higher achievement in science, but it could equally well be that students who already have high levels of achievement (and enjoyment, and interest) in science are likely to choose to spend their free time in this way.

It is interesting to note that although achievement was associated with *awareness* of environmental issues, there was no link between achievement and *concern* for environmental issues. Further, there was a *negative* relationship between achievement and *optimism* regarding environmental issues. It could be that students who are high achievers, with greater awareness of environmental issues, are better equipped to understand the difficulties involved in finding solutions for environmental problems.

Differences by gender

The previous chapter examined the science-related knowledge and attitudes of New Zealand students as a whole, compared with their counterparts in the other PISA 2006 countries. The report now looks at the differences between groups of students within New Zealand. This chapter deals with gender.

Scientific literacy

New Zealand's 15-year-old boys and girls achieved a similar mean score on the scientific literacy scale (528 and 532 respectively) as was the case for 21 of the other 29 OECD countries. Boys performed significantly more strongly than girls in six countries (including the United Kingdom), while girls out-performed boys in only two countries (Turkey and Greece).

Only boys in Finland (562) and Hong-Kong China* (546), on average, performed significantly better than boys in New Zealand. Girls in Finland (565) also performed strongly, and on average were the only girls in PISA 2006 to significantly outperform New Zealand's 15-year-old girls.

Proficiency levels

New Zealand and Finland were the only countries with at least 3 percent of girls and 4 percent of boys achieving the highest level of proficiency, Level 6. A similar proportion of New Zealand's girls (16.9%) and boys (18.4%) were proficient at Level 5 or higher.

New Zealand boys were slightly more likely than girls to be at the top and the bottom ends of the scale. A larger proportion of boys (15.3%) than girls (12.2%) did not demonstrate proficiency above Level 1 (5% of boys and 3% of girls did not reach Level 1).

Scientific literacy competencies

On the three separate scientific competencies, the performance of New Zealand boys and girls was markedly different (see Table 4).

Table 4: Mean scores on the scientific literacy competencies, by gender

Student grouping	Identifying scientific issues		Using scientific evidence		Explaining phenomena scientifically	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
New Zealand girls	547	(3.7)	541	(4.3)	517	(3.6)
Girls OECD mean	508	(0.6)	501	(0.7)	493	(0.6)
New Zealand boys	525	(3.7)	532	(4.4)	528	(4.0)
Boys OECD mean	490	(0.7)	498	(0.8)	508	(0.7)

Identifying scientific issues

New Zealand girls' performance was significantly stronger, with a 22-point advantage over boys. This was similar to the difference found in other OECD countries (a 17-point mean difference in favour of girls[12]). The proportion of girls achieving Level 5 or above (20.2%) was higher than for boys (16.7%); conversely, a higher proportion of New Zealand boys were at Level 1 or below (15.5%, compared with 9.3% of New Zealand girls). Nevertheless, the proportion of New Zealand boys achieving at the higher levels was greater than in any other participating country (with the exception of Finland (20.1%) this was also the case for girls).

Using scientific evidence

Here also, New Zealand girls' performance was stronger, but in this case the difference was not statistically significant. Across the 30 OECD countries only two showed significant gender differences (Turkey and Greece), and this was in favour of girls. The proportions of New Zealand boys and girls achieving Level 5 or above were similar (21.9% and 22.8% respectively). However, New Zealand boys were more likely to be at Level 1 or below (17.5%, compared with 13.6% of girls).

Explaining phenomena scientifically

On this scale New Zealand boys significantly outperformed the girls. A smaller proportion of New Zealand girls (14.1%) achieved Level 5 or above compared with boys (18.8%), although the proportion of boys and girls at Level 1 or below was the same (16.1%).

It should be noted that New Zealand boys' performance on the three scales was consistent (mean scores from 525 to 532). Girls' performance varied much more, as they scored well below the boys on one scale and well above on the other two. Across the OECD countries, girls were weakest at *explaining phenomena scientifically*, although the difference (15 points, from lowest mean of 493 to highest mean of 508) was half that seen among New Zealand girls (30 points, from 517 to 547).

Scientific knowledge domains

Table 5 shows the average scores obtained by girls and boys in New Zealand, and across the OECD, for the three assessed knowledge content areas. There was no gender difference in New Zealand on the *living systems* scale, but boys were stronger on the other two content areas: *earth and space systems* (12 score points) and *physical systems*, where the difference was most marked (26 score points). Interestingly, in TIMSS there was no gender difference on the 'physical science 'or 'living science' scales, but Year 5 boys also showed a stronger performance than girls on 'earth science'.[13]

12 Differences are calculated on un-rounded figures. As a result the difference between the mean for OECD girls (508) and boys (490) is 17 points.

13 As noted earlier, it is important to take into account the fact that the conceptual frameworks for PISA and TIMSS differ.

Table 5: Mean scores on the science content areas, by gender

Gender groupings	Living systems		Earth and space systems		Physical systems	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
New Zealand girls	527	(4.0)	524	(3.4)	503	(3.5)
Girls OECD mean	500	(0.6)	491	(0.6)	487	(0.6)
New Zealand boys	529	(3.7)	536	(3.3)	529	(3.4)
Boys OECD mean	504	(0.6)	508	(0.6)	513	(0.6)

In terms of students' knowledge *about* science (scientific enquiry and explanations), New Zealand girls significantly outperformed boys (mean score 546, compared with boys 532). This gender pattern was also observed in five of the other high-performing countries (Finland, Estonia*, Korea, Australia and Canada).

Attitudes to science

There were no significant differences between New Zealand boys and girls in terms of interest in science or motivation. However, a significantly greater proportion of boys enjoyed science. Boys were also more likely to report that they were good at science and would be able to perform a selection of scientific literacy tasks.

New Zealand boys were more likely than girls to report engagement in science-related leisure activities. They were also more likely to regard advances in science as important, although a higher proportion of girls expected to be in a science-related career at age 30.

Boys were more likely to report awareness of environmental issues, but girls were more likely to express high levels of concern for the environment. Girls were less optimistic about solving problems but more likely to report a sense of responsibility for sustainable development.

Differences by ethnicity: student factors

New Zealand students participating in PISA 2006 were asked to state which ethnic group(s) they identified with. To assign students to one ethnic grouping, a hierarchal classification system was used, which prioritises ethnicity in the following order: Māori, Pasifika, Asian, 'Other' and Pākehā/European. For example, if a student identified as both Māori and Pasifika, they were included in the Māori ethnic grouping. Using this classification system, the ethnic background of PISA students broadly mirrored the ethnic composition of New Zealand's 15-year-old school population (see Table A1.1 in Appendix 1). The discussion in this chapter focuses on the four main ethnic groupings: Pākehā/European, Māori, Pasifika and Asian. The 'Other' ethnic group was too small for meaningful analysis.

Scientific literacy

As Table 6 shows, Pākehā/European students, on average, performed significantly better than students who identified with one of the other three main ethnic groupings: Asian, Māori or Pasifika. Asian students, on average, performed better than Māori and Pasifika 15-year-olds, while the science performance of Māori was stronger than that of Pasifika students.

Table 6: Mean scientific literacy scores, by gender, within ethnic groupings

Ethnic groupings and students overall	All		Girls		Boys	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Pākehā/European	554	(2.4)	554	(3.6)	554	(3.6)
Māori	480	(4.9)	484	(5.8)	477	(7.6)
Pasifika	454	(8.7)	452	(10.2)	456	(10.9)
Asian	542	(6.4)	540	(8.8)	543	(8.6)
All students	530	(2.7)	532	(3.6)	528	(3.9)
OECD mean	500	(0.5)	499	(0.6)	501	(0.7)

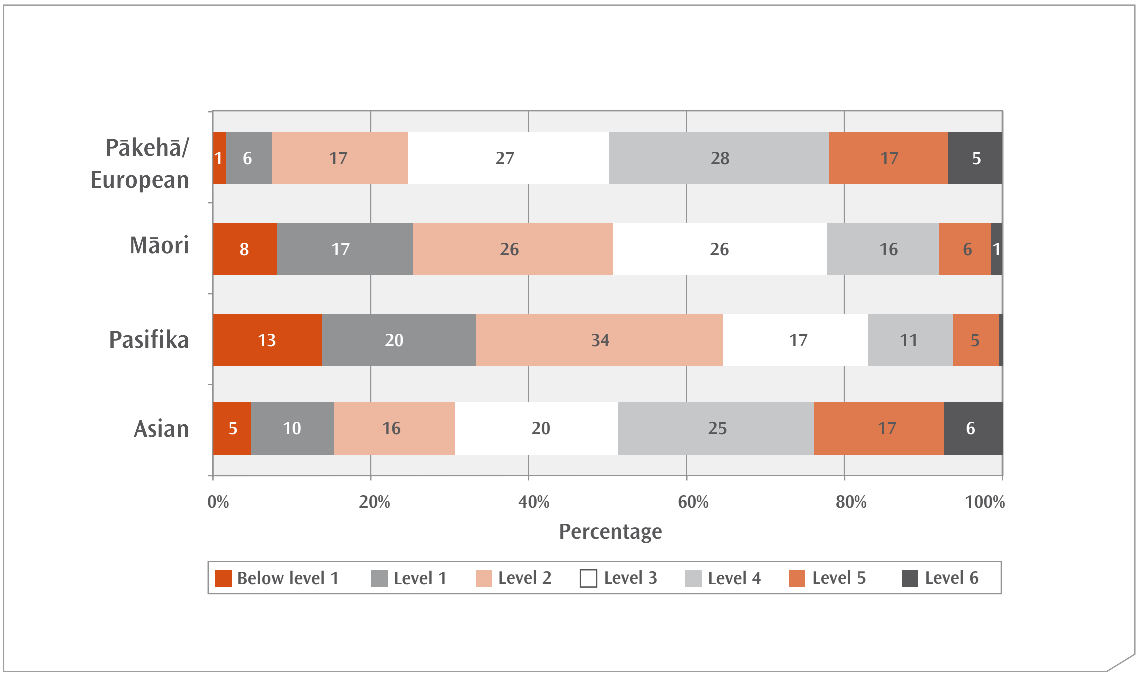
Note: Because the proportion of students classified as 'Other' was small (2%), they are not reported.

However, as shown in the figures below, it is important to bear in mind that high- and low-achieving students could be found in all ethnic groupings. Within each ethnic group there was no significant difference in the performance of boys and girls.

Proficiency levels

A relatively large proportion of Pākehā/European and Asian students were proficient at Level 6, the highest level of scientific literacy. As can be seen in Figure 3, the proportion of Māori and Pasifika students achieving Level 6 was much smaller, and the same was true at Levels 4 and 5. In total, around half of Pākehā/European and Asian students were proficient in science at Level 4 or higher, but only about one-quarter of Māori and just over 15 percent of Pasifika students achieved these levels.

Figure 3: Percentage of students at the six proficiency levels, by ethnic grouping



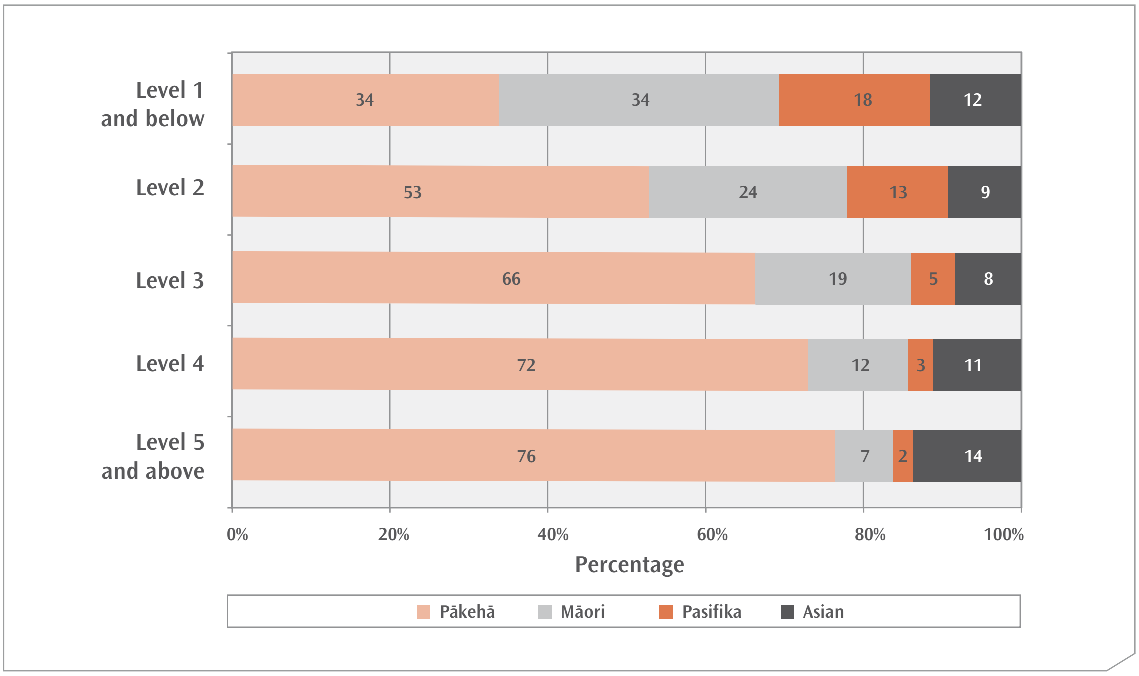
Note: Because the proportion of students classified as 'Other' was small (2%), they are not reported.

At the other end of the scale, nearly one-quarter of Pākehā/European, one-third of Asian, one-half of Māori and two-thirds of Pasifika students did not show proficiency above Level 2. Seven percent of Pākehā/European, 15 percent of Asian, one-quarter of Māori and one-third of Pasifika students did not demonstrate proficiency beyond Level 1.

The findings reported above examine the distribution of students by ethnicity *across* each of the six proficiency levels. Another way of looking at the relationship between ethnicity and achievement is the ethnic composition *within* proficiency levels. Given that over 60 percent of the PISA 2006 students were in the Pākehā/European ethnic group[14], one would expect a similarly large proportion within each proficiency level. However, of those New Zealand students that did not demonstrate proficiency above Level 1, only one-third (33.6%) were Pākehā/European, the same proportion as Māori (34.3%). Pasifika students (8% of the sample) made up 18 percent of this group.

14 See Appendix 1, Table A1.1 for the ethnic composition of the PISA sample and the 15-year-old school population.

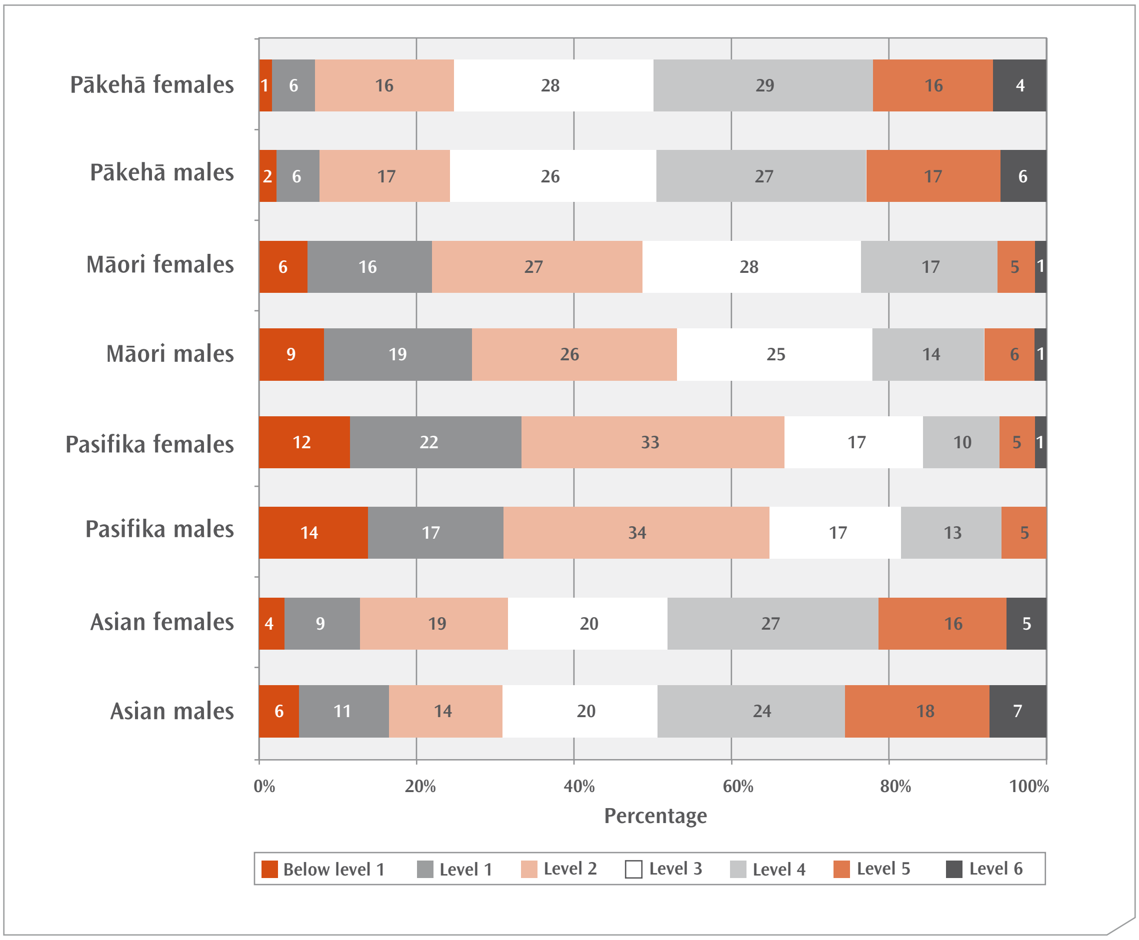
Figure 4: Percentage of students across ethnic groupings at the six proficiency levels



Note: Because the proportion of students classified as 'Other' was small (2%), they are not reported.

As can be seen in Figure 5, a slightly larger proportion of Asian and Pākehā/European boys achieved Level 5 or higher than their female counterparts. However, none of the gender differences within ethnic groupings were statistically significant.

Figure 5: Percentage of students at the six proficiency levels, by gender, within ethnic groupings



Note: Because the proportion of students classified as 'Other' was small (2%), they are not reported.

Scientific literacy competencies

As noted above (Chapter 2, Scientific literacy competencies), New Zealand students performed least strongly (relative to the OECD mean) on the *explaining phenomena scientifically* scale. Table 7 shows that this was true of all ethnic groups.

Table 7: Mean scores on the science competencies, by ethnic grouping

Ethnic groupings and students overall	Identifying scientific issues		Using scientific evidence		Explaining phenomena scientifically	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Pākehā/European	560	(2.6)	562	(2.9)	547	(2.5)
Māori	487	(5.7)	481	(6.4)	471	(5.1)
Pasifika	465	(8.6)	455	(10.0)	443	(9.0)
Asian	540	(6.3)	555	(7.4)	534	(6.8)
All New Zealand students	536	(2.9)	537	(3.3)	522	(2.8)
OECD mean	499	(0.5)	499	(0.6)	500	(0.5)

Note: Because the proportion of students classified as 'Other' was small (2%) they are not reported.

Table 8 shows gender differences within ethnic groupings for each of the science literacy competencies. While the performance of girls from all ethnic groupings was stronger than that of boys on the *identifying scientific issues* scale, this difference in favour of girls was only significant for Pākehā/European (20 points) and Māori (24 points) students. The gender differences for Pasifika (15 points) and Asian (12 points) students were not significant, possibly because of their relatively small sample size[15].

Table 8: Mean scores on the science competencies, by gender, within ethnic groupings

Student groupings	Identifying scientific issues		Using scientific evidence		Explaining phenomena scientifically	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Pākehā/European girls	570	(3.6)	565	(4.0)	539	(3.6)
Pākehā/European boys	550	(3.5)	558	(4.2)	555	(3.9)
Māori girls	500	(7.0)	487	(7.3)	469	(5.7)
Māori boys	476	(7.6)	476	(8.7)	472	(8.1)
Pasifika girls	472	(10.5)	455	(11.9)	435	(11.2)
Pasifika boys	457	(10.8)	456	(12.1)	453	(10.1)
Asian girls	547	(9.2)	557	(9.8)	525	(9.6)
Asian boys	534	(7.8)	554	(9.7)	542	(8.3)

Note: Because the proportion of students classified as 'Other' was small (2%), they are not reported.

On the *explaining phenomena scientifically* scale, Māori boys and girls had very similar scores. Boys out-performed girls in all other ethnic groups, but the difference was only significant for Pākehā/European students (possibly due to the small size of the Asian and Pasifika samples). Boys and girls within each of the four ethnic groupings achieved a statistically similar result on the *using scientific evidence* scale.

15 As noted earlier, differences are calculated on un-rounded figures. As a result the difference between Māori girls (500) and boys (476) is 24 points, and between Asian girls (547) and boys (534), 12 points.

Scientific knowledge domains

As noted earlier (Chapter 2, Scientific literacy), New Zealand students' performance was weaker in *physical systems* (relative to the OECD mean) than in the other two content areas. This was true within all ethnic groupings (Table 9).

Table 9: Mean scores on the science content areas, by ethnic grouping

Ethnic groupings and students overall	Living systems		Earth and space systems		Physical systems	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Pākehā/European	551	(2.4)	549	(2.4)	536	(2.3)
Māori	481	(5.1)	487	(4.2)	473	(4.2)
Pasifika	455	(9.0)	465	(7.8)	449	(8.1)
Asian	538	(7.6)	540	(6.0)	528	(6.2)
All students	528	(2.7)	530	(2.4)	516	(2.4)
OECD mean	502	(0.5)	500	(0.5)	500	(0.5)

Note: Because the proportion of students classified as 'Other' was small (2%), they are not reported.

Attitudes to science

Asian students were consistently more positive than other students in terms of interest in science, enjoyment of science and general motivation to learn science. Māori students were least positive in terms of enjoyment and instrumental motivation, but on interest in science and future-oriented motivation they were as likely to be positive as their Pākehā/European peers, although less likely than Pasifika and Asian students.

The generally more positive attitude of Asian students to science was reflected in many of their responses. They were more likely to report that they were good at science and would be able to perform a selection of scientific literacy tasks. Māori students were least likely to report that they were good at science. Both Māori and Pasifika students were less likely to be confident about performing science tasks. Asian students, followed by Pasifika students, were more likely to report involvement in science-related leisure activities.

Asian students were more likely to regard advances in science as important and useful, and were more likely to wish to pursue scientific studies or careers. Māori students were least likely to give positive responses to these questions.

Asian students were most likely to be aware of environmental issues and to have a sense of responsibility for sustainable development. However, there was no significant difference between ethnic groupings in their level of concern for environmental issues. Asian and Pasifika students were more likely to be optimistic that environmental problems would be solved than the other two ethnic groupings.

Family background

Achievement in and attitudes to science (and other subjects) can be influenced by family background. In this chapter we report on the analysis of differences by a range of family-related factors: family socio-economic background, family composition, parents' educational qualifications, the immigration status of students and parents, educational resources in the home, and student mobility.

Socio-economic status

Students participating in PISA were asked questions about their parents' occupational status and highest educational levels. They were also asked whether they had in their homes a range of education-related and household items; these were used as a proxy for parental income. Based on their responses, PISA developed an index that is known as 'economic, social and cultural status' (ESCS).[16] However, in this report the common term 'socio-economic status' or 'SES' is used.

As noted in the PISA 2006 international report (OECD 2007a), the PISA results show that poor performance at school does not automatically follow for students from low income households where parents have few educational qualifications, but that socio-economic status is one of the most powerful factors influencing student performance. Families with a high level of education and income are generally in a better position to provide their children with enhanced learning experiences and opportunities than families with a less advantaged socio-economic background.

Student scores on PISA's SES index were standardised to give an OECD mean of zero. Countries with a positive mean score were thus above the OECD average in terms of the socio-economic background of their students, while those with a negative score were below. The mean score for New Zealand's 15-year-olds was 0.10: above the OECD average, but not as high as some of the other top-performing countries; for example, Canada (0.37), Finland (0.26) and the Netherlands (0.25) - see Table 12 for the mean SES index for the other countries.

New Zealand students were assigned to one of four equal groups according to their family's estimated position on the socio-economic index: *low* (the bottom 25 percent), low/medium (the next 25 percent), medium/high and high (the top 25 percent). Pākehā/European students were over-represented in the high group and under-represented in the low group; the reverse was true of Māori and Pasifika students (for details, see Table A1.2 in Appendix 1).

16 This index is derived from the following indices: the index of the highest socio-economic occupational status of parents of the student's mother or father, highest educational level of parents and home possessions. The last of these was obtained by asking students whether they had in their home: a desk to study at, a room of their own, a quiet place to study, a computer they could use for school work, educational software, a link to the internet, their own calculator, classic literature, books of poetry, works of art (eg, paintings), books to help with their school work, a dictionary, a dishwasher, a DVD player or VCR, the number of cell phones, televisions, computers, cars, and books at home, and three country-specific items (for New Zealand, these were broadband connection, digital camera and clothes dryer). Access to relevant household items was used as a proxy for parental income.

As Table 10 illustrates, overall the higher the student's family socio-economic background, the higher the students' mean science performance. This relationship between socio-economic background and performance for New Zealand's 15-year-olds was also observed across all other PISA countries. However, some countries achieved similar science achievement among students from different socio-economic backgrounds, and many students from lower socio-economic backgrounds, including New Zealand students, achieved high performance (OECD forthcoming, a). As noted in a recent OECD report, some education systems "are even more conducive for students from relatively disadvantaged backgrounds to become top performers in science" (OECD 2009d, p. 11). A third or more of the top performers in science from Japan, Finland and Austria, as well as the non-OECD countries of Macao-China* and Hong Kong-China*, came from socio-economic backgrounds below the average of the country. In New Zealand the proportion was one-quarter. This was also the average for all OECD countries.

Table 10: Mean scores on the scientific literacy scale, by socio-economic grouping

Socio-economic grouping	Mean score	Standard error
Low	480	(4.4)
Low-medium	516	(3.5)
Medium-high	547	(3.4)
High	590	(3.3)

As Table 10 shows, the science achievement of 15-year-olds was strongly related to socio-economic status. This was the case within all four main ethnic groupings, as shown in Table 11. Of note, Pasifika students from families with a 'high' socio-economic family background (549) achieved a result that was 69 points higher than the average for 'medium-high' students, and 95 points higher than the average for all 15-year-old Pasifika students (454).

Table 11: Mean scores, by socio-economic status, within ethnic groupings

Socio-economic grouping	Pākehā/European		Māori		Pasifika		Asian	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Low	512	(4.8)	450	(6.9)	432	(12.2)	487	(11.7)
Low-medium	531	(3.9)	484	(7.2)	456	(12.7)	521	(11.9)
Medium-high	560	(3.8)	507	(8.6)	480	(14.6)	548	(9.6)
High	598	(3.6)	540	(10.7)	549	(19.7)	593	(9.8)

Using the average socio-economic background of 15-year-olds in each country, it is possible to measure and compare the extent to which socio-economic factors relate to student performance.[17] Of the 11 top-performing countries, New Zealand showed the strongest relationship between student performance and socio-economic background, comparable to that in the United States and the United Kingdom (see Table 12 for score point difference in science associated with one unit on the PISA SES index).

17 See OECD 2007b, Table 4.4a, p. 124.

Table 12: Score point difference per ESCS unit and relationship with science performance, by country

Top-performing countries and the United Kingdom and United States	ESCS		Total variance in student performance	Score point difference in science associated with one unit on the ESCS index		Strength of the relationship between student performance and the ESCS	
	Mean index	Standard error	Percentage of the average variance in student performance	Score point difference	Standard error	Percentage of explained variance in student performance	Standard error
Australia	0.21	(0.01)	110.6	43	(1.5)	11.3	(0.78)
Canada	0.37	(0.02)	97.5	33	(1.4)	8.2	(0.68)
Finland	0.26	(0.02)	81.4	31	(1.6)	8.3	(0.87)
Japan	-0.01	(0.02)	109.4	39	(2.7)	7.4	(0.95)
Korea	-0.01	(0.02)	90.2	32	(3.1)	8.1	(1.49)
Netherlands	0.25	(0.03)	101.2	44	(2.2)	16.7	(1.65)
United Kingdom	0.19	(0.01)	124.4	48	(1.9)	13.9	(1.12)
United States	0.14	(0.04)	124.7	49	(2.5)	17.9	(1.63)
Chinese Taipei*	-0.31	(0.02)	99.1	42	(2.1)	12.5	(1.19)
Estonia*	0.14	(0.02)	77.9	31	(2.0)	9.3	(1.12)
Hong Kong-China*	-0.67	(0.03)	93.4	26	(2.3)	6.9	(1.26)
Liechtenstein*	0.19	(0.05)	104.0	49	(5.5)	20.4	(4.42)

Source: OECD 2007b, Tables 4.4a, p. 124; 4.1a, p. 96; and 4.4c, p. 127.

*Note: *denotes non-OECD countries.*

Students from high socio-economic backgrounds (the top quarter of the index) tended to have higher engagement with science than those from low (bottom quarter) socio-economic backgrounds. They also tended to report higher scientific self-belief, had greater engagement in science-related leisure activities and valued science more highly. They reported a higher level of environmental awareness and responsibility for sustainable development, although there was no difference in level of concern for the environment. However, students from *low* socio-economic backgrounds tended to be more optimistic about solving environmental problems.

Country of birth (immigrant status)

PISA uses the term *native* to refer to students who were born in the country of the assessment and/or have at least one parent born in the same country. It is noteworthy that in three of the top-performing OECD countries all, or almost all, of their students were native: Korea (100%), Japan (99.6%) and Finland (98.5%). In only five of the 30 OECD countries – Canada (78.9%), New Zealand (78.7%), Australia (78.1%), Switzerland (77.6%) and Luxembourg (63.9%) – less than 80 percent reported that they were native to their country. This is likely to have different implications for education systems because it is related to factors such as language, as highlighted below.

Among the PISA students in New Zealand, 14 percent were born outside New Zealand with parents also born elsewhere (*first-generation students*), and seven percent were born in New Zealand but their parents were not (*second-generation students*).[18]

Table 13 shows the performance of New Zealand students by immigrant status. While the native students' mean science performance was 10 points higher than first-generation students, this difference was not statistically significant. However, second-generation students' science performance was significantly weaker than that of first-generation students (18 points difference). New Zealand was the only OECD country to show this phenomenon of first-generation students outperforming second-generation students.

Table 13: Mean scores, by immigration status

Immigration status	All students			
	Percentage of students	Standard error	Mean score	Standard error
Native	78.7	(1.0)	536	(2.6)
Second-generation	6.9	(0.6)	508	(8.0)
First-generation	14.3	(0.7)	526	(6.6)

In order to explain this finding it is necessary to look at the ethnic composition of the immigrant status groups (see Table A1.3 in Appendix 1). As Asian and Pākehā/European 15-year-olds achieved high average science performance, and students from these ethnic groupings comprised 85 percent of the *first-generation students*, it is not surprising that the *first-generation* students achieved scores close to those of *native* students.

In contrast, Pasifika constituted the largest proportion (44.7%) of *second-generation* students, while the proportion of Asian (29.3%) and Pākehā/European students (22.6%) within this group was smaller. Given that the mean science achievement for Pasifika students overall was low, this could explain why *second-generation* students performed less well than *first-generation* students.

Table 14 compares performance by immigrant status *within* and *across* ethnic groups. Second-generation Pasifika students significantly outperformed their first-generation peers, and those native to New Zealand significantly outperformed both other groups. Among Asian students, the ordering was the same, although the difference between native and second-generation students was not significant. There was relatively little variation by immigrant status among Pākehā/European students, possibly because the recent immigrants, although not all are English speaking, had fewer language difficulties to contend with (see further below).

18 Note that the labels for these groupings differ from those used in PISA 2000 and 2003: first-generation was previously referred to as 'non-native' and second-generation was referred to as 'first-generation'.

Table 14: Mean scores, by immigration status, within ethnic groupings

Immigration status	Pākehā/European		Pasifika		Asian	
	Mean score	Standard error	Mean score	Standard error	Mean score	Standard error
Native	553	(2.4)	497	(9.5)	587	(15.1)
Second-generation	567	(9.9)	437	(10.5)	573	(8.8)
First-generation	564	(6.9)	399	(14.8)	527	(8.6)

Note: The number of 15-year-old Māori students who identified as first- or second-generation is too small to be included in this analysis.

Language spoken in the home

As part of the student questionnaire, students were asked what language they spoke in their home most of the time. As Table 15 shows, the large majority of New Zealand's 15-year-olds indicated that their home language was English. Very few Pākehā/European (1%) and Māori (1%) students did not speak English at home most of the time.

The mean achievement of all 15-year-olds with English as a home language was significantly higher (42 points[19]) than for those who spoke another language.

Table 15: Mean scores, by home language (all students, Pasifika and Asian)

Student grouping	English (language of the test)				Other language			
	Percentage of students	Standard error	Mean score	Standard error	Percentage of students	Standard error	Mean score	Standard error
Pasifika	79.0	(2.9)	473	(8.0)	21.0	(2.9)	402	(15.6)
Asian	45.8	(2.3)	565	(8.8)	54.2	(2.3)	525	(8.2)
All students	91.0	(0.6)	538	(2.4)	9.0	(0.6)	497	(7.8)

Note: The proportion of Pākehā/European and Māori students who do not speak English at home most of the time was too small for analysis.

Just over one-half of 15-year-old Asian students reported that they did not speak English at home most of the time. Asian students with English as their home language achieved a significantly higher mean science score (by 40 points) than their counterparts who did not.

The difference in performance for students who did not speak English in the home was particularly marked for Pasifika students. A 70 score-point advantage was observed for the 79 percent of Pasifika students who spoke English at home most of the time, when compared to Pasifika students who did not.

Parents' highest level of education

Students were asked to report their parents' highest level of education. To examine the relationship between students' science achievement and parental education, the highest educational qualification of each parent was used.

As Table 16 demonstrates, on average the higher the parents' educational level, the stronger the mean science achievement. The difference in the mean scores of students with fathers at the lowest and highest levels of education was nearly 100 points, which was greater than the corresponding difference based on the mother's education.

19 As noted earlier, differences are calculated on un-rounded figures. As a result the difference between those who spoke English at home (538) and those who do not (497) is 42 points.

Table 16: Mean scores, by the highest educational level of parents

Level of parental education	Mother				Father			
	Mean score	Std error	Percentage of students	Std error	Mean score	Std error	Percentage of students	Std error
Did not complete primary school or completion of primary/secondary schooling unknown	485	(8.3)	3.9	(0.3)	468	(8.5)	4.1	(0.3)
Completed primary or lower secondary schooling	503	(5.1)	13.0	(0.6)	505	(4.8)	12.2	(0.6)
Completed upper secondary schooling	534	(3.1)	39.8	(0.9)	536	(3.0)	47.8	(1.0)
Completed tertiary education	559	(3.3)	43.3	(1.0)	565	(3.6)	35.9	(1.0)

Notes: Completed primary or lower secondary schooling includes parents who completed at least Year 6 (Standard 4) and left school before the end of Year 10 (Form 4) to those who completed at least Year 10 (Form 4) with or without School Certificate.

Completed upper secondary schooling includes parents with a qualification to enter a degree course or a trade or national certificate (eg, an apprenticeship).

Completed tertiary education includes parents with a diploma (eg, teaching, nursing, business studies, etc) and a degree or higher (eg, Bachelor of Arts/Science/Nursing/Education etc).

Standard errors appear in parenthesis.

Family structure: single-parent or other type of family

To investigate whether the family structure of a student was related to science achievement (that is, single-parent family versus other type of family), the questionnaire asked students who usually lived at home with them.[20]

As can be seen in Table 17, 15-year-old students from single-parent families (513) in 2006, on average, performed significantly lower than those from other family types (537). However, single-parent families are over-represented in the lower socio-economic groupings and those students have, on average, lower performance (see Table 10). When socio-economic factors are taken into account, within each socio-economic grouping no statistical difference was observed between the mean performance of students from single-parent families and other family types.

Table 17: Mean scores, by family structure, within socio-economic groupings

Socio-economic groupings	Single families				Other family types			
	Percentage of students	Std error	Mean score	Std error	Percentage of students	Std error	Mean score	Std error
Low socio-economic	29.3	(1.4)	475	(6.5)	70.7	(1.4)	482	(5.4)
Low-medium socio-economic	20.0	(1.1)	511	(7.4)	80.0	(1.1)	517	(4.1)
Medium-high socio-economic	16.5	(1.1)	541	(7.5)	83.5	(1.1)	548	(3.7)
High socio-economic	13.0	(1.0)	577	(7.5)	87.0	(1.0)	592	(3.4)
All students	20.0	(0.6)	513	(4.4)	80.0	(0.6)	537	(2.9)

Note: Standard errors appear in parenthesis.

20 See Cotterell et al. 2008, which examines the links between parental educational qualifications and family structure.

Students' access to educational resources in the home

To ascertain students' level of access to educational resources in the home, the questionnaire asked students to indicate whether they had a desk to study at; a quiet place to study; a computer to use for school work; books to help with school work; and educational software. As shown in Table 18, approximately 90 percent of New Zealand students reported they had the first four resources. Within each of the four main ethnic groupings, this was true of at least 80 percent of the students, but Pasifika and Māori 15-year-olds were less likely to have access to educational resources at home than their Pākehā/European and Asian peers.

A smaller proportion of 15-year-olds reported having educational software, and this was the case within all ethnic groupings. However, as with the other resources, Pākehā/European and Asian students were more likely to have access to educational software.

Students with access to each of the resources achieved a significantly better mean performance than those who did not, but the difference was smaller for educational software.

Table 18: Mean scores, by access to educational resources, students overall and ethnic grouping

Educational resources	Students overall			Ethnic groupings			
	Yes resource		No resource	Pākehā-European	Māori	Pasifika	Asian
	Percentage of students	Mean score	Mean score	Percentage of students			
A desk to study at	86.2 (0.6)	539 (2.5)	492 (5.3)	87.8 (0.5)	78.0 (1.8)	79.7 (3.2)	94.8 (1.1)
A quiet place to study	88.4 (0.5)	538 (2.5)	489 (5.6)	90.6 (0.5)	83.5 (1.3)	77.9 (2.2)	92.0 (1.3)
A computer to use for school work	92.5 (0.5)	537 (2.5)	471 (7.1)	95.4 (0.4)	84.3 (1.8)	80.2 (2.7)	97.2 (0.7)
Books to help with school work	86.4 (0.5)	538 (2.6)	499 (5.3)	87.4 (0.4)	80.5 (1.4)	85.1 (2.1)	91.5 (1.3)
Educational software	65.2 (0.8)	543 (2.6)	518 (3.8)	68.6 (1.0)	57.1 (2.1)	55.8 (3.0)	67.1 (1.8)

Notes: Percentages are based on total respondents to the student questionnaire and may be a slight underestimate of the percentage of the population.

Standard errors appear in parenthesis.

Student mobility between schools

To investigate whether changing schools frequently over the 10 years of compulsory schooling affected science achievement, students were asked to indicate how many primary, intermediate, secondary or other type (eg, kura kaupapa) of schools they had attended.[21] As Table 19 shows, students who had not changed school (except to move from primary/intermediate to secondary) had the highest scores; those who had attended three or more schools of one type had the lowest scores.

Table 19: Mean scores, by number of schools attended at any level

Number of schools attended at any level	Percentage of students	Standard error	Mean score	Standard error
No more than 1	44.2	(0.9)	543	(2.9)
2	35.4	(0.8)	534	(3.1)
3 or more	20.4	(0.7)	513	(4.2)

Note: Does not include transition from primary/intermediate to secondary schooling.

21 The effect of the frequent moving of schools was explored by Bull and Gilbert (2007), who found that students who moved more frequently had a lower sense of belonging to school, which was particularly marked for Year 11 students.

School background

In this chapter we look first at overall differences between schools (did some obtain better results than others?) and within schools (what was the average range of student performance?). We go on to consider a range of school-related variables which may have an impact on student achievement, looking first at school factors (derived from information supplied by principals of PISA schools) and then at student factors, based on responses given by individual PISA participants who completed the student questionnaire. Finally, we look at parents' perceptions of school quality.

School characteristics

School characteristics (size, decile[22], etc) have been explored in detail in a separate report (Caygill & Sok 2008) but are summarised briefly here to complete the picture of PISA findings. Generally speaking, higher science literacy scores were obtained by:

- students in large schools rather than small schools
- students in urban rather than rural schools
- students in high-decile rather than low-decile schools

These factors are, of course, inter-related, since large schools tend to be in urban locations and are often high-decile schools.

Variation between and within schools

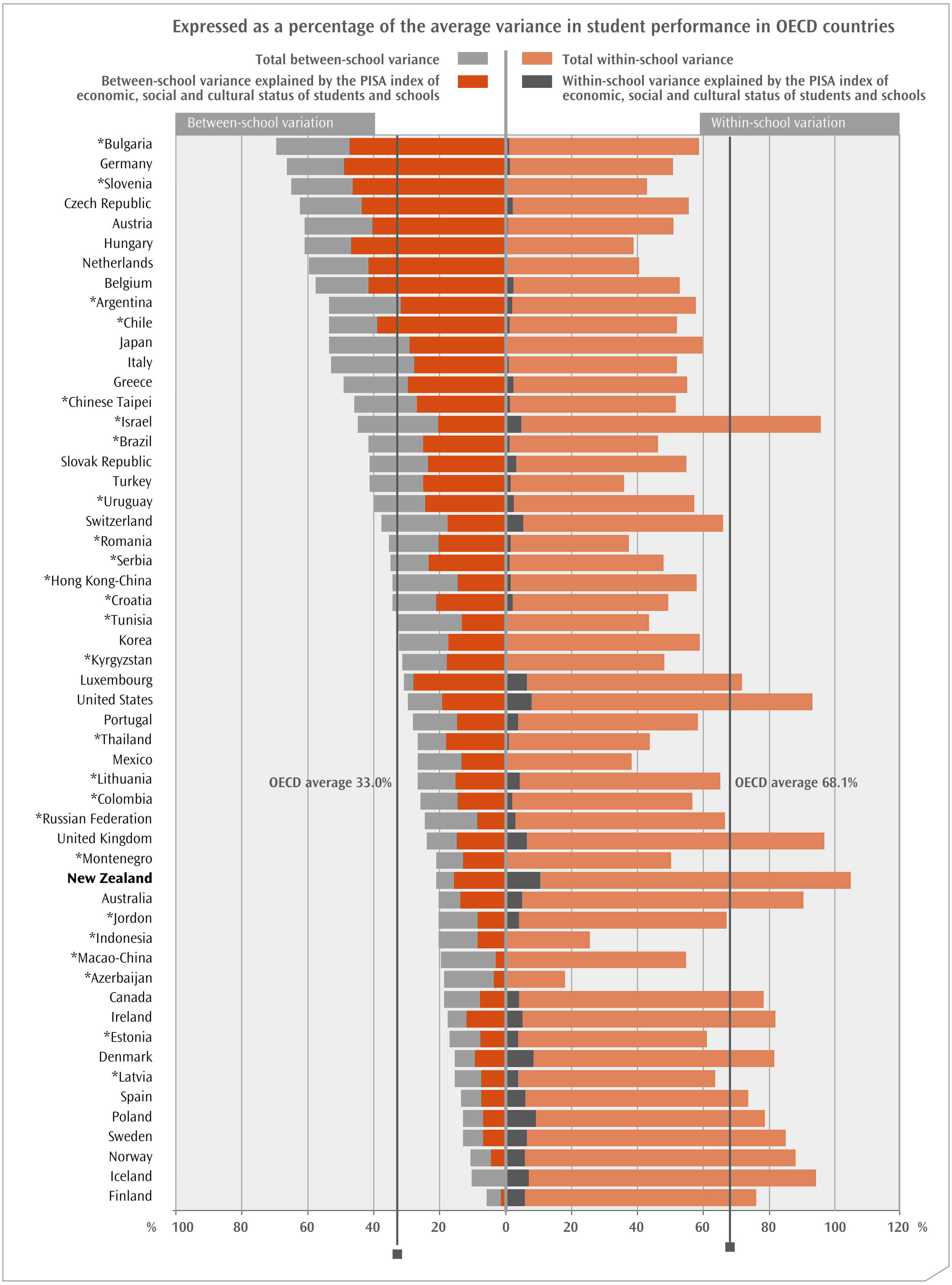
There were differences in students' science literacy *between* schools and also *within* schools, in New Zealand and in other PISA countries. Large between-school variation indicates large differences between the mean scores of different schools, whereas a small between-school variation indicates that the average performance of schools is similar. Schools where all students achieved similar scores would have a very small within-school variation, while schools with both very high and very low achievers would have a large within-school variation.

Figure 6 shows, for each OECD country, how much variation in student performance there was between schools and how much was within schools.[23] The grey bars to the left of the central line indicate the variation in student science performance between schools, while the orange bars on the right show the variation in average student science performance within schools. The length of the bars shows the extent of the variation.

22 School decile is derived from household income, household crowding, income support (excludes family support), parental occupation and education qualifications. For further information see the Ministry of Education's website.

23 To measure the variation between and within schools, a multi-level model was fitted to the data. The model identifies the variation attributable to differences in student results obtained by students in different schools (between-school variance) and that attributable to the range of student results within schools (within-school variance).

Figure 6: Variance in student performance between schools and within schools



Source: OECD 2007a, Figure 4.1, p. 171.

Notes: The average variance of OECD countries is used as the basis for percentages in this figure, and so the percentages for each country do not sum to 100.

**denotes non-OECD countries.*

Across the OECD countries, one-third of the variance in student performance was between schools and the remaining two-thirds within schools. With a greater overall variance, New Zealand (20.0%) was one of the countries where the variation between schools was smaller than the OECD average (33.0%) and the variation within schools was considerably larger (New Zealand, 106.0%; OECD, 68.1%).

Most of the other top-performing OECD countries also had a below-average variation between schools (the only exceptions were the Netherlands and Japan). In Finland the variation between schools was minimal (4.7%).

New Zealand showed the largest variation in 15-year-olds' mean science performance *within* secondary schools of all the PISA 2006 countries. The United Kingdom (97.8%), the United States (94.0%) and Australia (91.1%) also had a large variation in student science performance within their secondary schools.

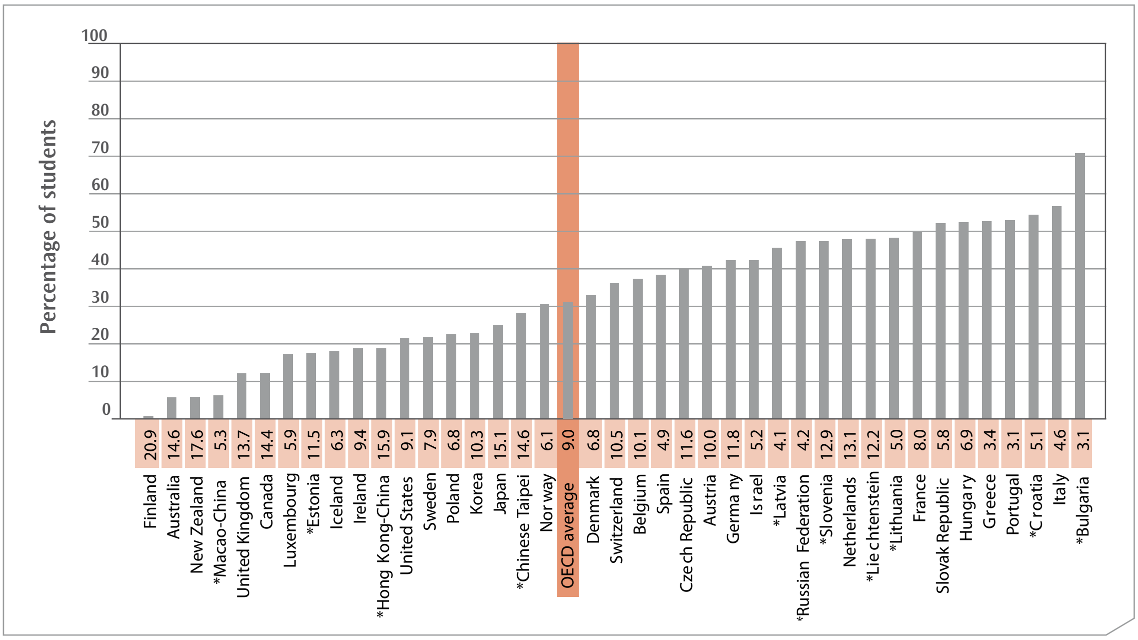
Figure 6 also shows how much of the variation in 15-year-olds' science performance between and within schools can be attributed to socio-economic factors (dark grey bars). Three-quarters of the variation between New Zealand's secondary schools can be explained by socio-economic factors, but these factors can explain only a very small part of the within-school variation. In the other top-performing countries[24] and in the United Kingdom and the United States, the impact of socio-economic factors on the variation of student performance within their secondary schools was even smaller than New Zealand's.

In short, the findings show that *within* New Zealand's secondary schools the science ability of 15-year-olds is very diverse. In contrast, relative to many other PISA countries, the variation in mean science performance of students *between* secondary schools is relatively small.

Percentage of schools with top performers

Figure 7 shows the percentage of 15-year-olds who attended schools where there were no top performers in science. In New Zealand more than ninety percent of students were in schools attended by New Zealand's top performers. This was also the case for Finland, Australia and the partner country Macao-China.

Figure 7: Percentage of students in schools with no top performers



Source: OECD 2009d, p. 45.

*Notes: Data on an orange background are percentages of top performers, eg, 17.6% of New Zealand's 15-year-olds were top performers. *non-OECD countries.*

24 Not including Liechtenstein*, for which there were insufficient observations to provide reliable estimates.

Student year levels

The aim of PISA is to measure the cumulative yield of students' knowledge and skills after they have completed around 10 years of compulsory education. In each country, students eligible to take part in PISA were those aged between 15 years 3 months and 16 years 2 months at the time of testing, regardless of their school year level.[25] In New Zealand the large majority of PISA students were in Year 11, with a small number from Year 10 or Year 12 (Table 20). Not surprisingly, students in higher year groups outperformed those in the lower levels.

Table 20: Percentage of PISA students at each year level

Year level	Percentage of PISA students	Standard error	Mean score	Standard error
Year 10	6.2	(0.4)	473	(6.9)
Year 11	89.4	(0.5)	531	(2.8)
Year 12	4.4	(0.3)	592	(8.4)

Science as a school subject

Students participated in PISA whether they were taking science as a school subject or not. In New Zealand, all students take science up to Year 10, but schools can decide whether it should be compulsory thereafter, so students in Years 11–13 may be able to choose whether or not to study a science subject.

The student questionnaire asked students to indicate whether they were taking any general science, biology, physics or chemistry subjects in the current year (2006), and whether these were optional or compulsory. As shown in Table 21, the majority of New Zealand students indicated they were taking a compulsory and/or an optional science subject. The proportion of students taking a compulsory course was 74 percent, below the OECD average of 84 percent, although the proportion taking a voluntary course was higher (New Zealand 43 percent, OECD average 29 percent).

Only 8 percent of New Zealand's Year 11 students reported they were not studying science at all, even though science may not be a compulsory subject at that year level. However, close to one-third of the PISA Year 12 students reported they did not take any science subjects.

Table 21: Mean scores, by whether taking science, within gender, ethnic and year groupings

Student grouping	Taking science (compulsory or optional)				No science	
	Percentage of students	Standard error	Mean score	Standard error	Mean score	Standard error
Girls	91.3	(0.7)	540	(3.5)	469	(8.7)
Boys	89.5	(1.0)	543	(3.6)	451	(7.2)
Pākehā/European	93.1	(0.6)	560	(2.4)	487	(8.2)
Māori	81.9	(2.4)	495	(4.6)	431	(9.9)
Pasifika	87.6	(1.9)	460	(9.6)	428	(16.8)
Asian	91.3	(1.1)	552	(6.3)	460	(17.4)
Year 10	89.2	(2.2)	486	(8.0)	415	(20.4)
Year 11	91.6	(0.7)	542	(2.7)	449	(7.1)
Year 12	69.0	(3.2)	619	(8.9)	535	(12.0)
All students.	90.4	(0.7)	541	(2.6)	459	(6.2)

Note: Because the proportion of students classified as 'Other' was small (2%) they are not reported.

25 As noted earlier, the testing took place in New Zealand schools between 24 July and 24 August 2006.

Not surprisingly, a very large difference was observed (more than 80 points) between the mean performance of the students who were taking science at school and those who were not. Girls were as likely as boys to be studying science at school, and there were significant differences in the mean achievement of both on the basis of whether they took science or not.

Students who were taking science as a school subject performed better than those who were not, within every year group and ethnic group. Only in the case of Pasifika students was the difference not significant, possibly due to the small numbers involved. The difference in mean science achievement was most marked for Asian students: the nine percent of Asian students who reported they did not take science, performed, on average, over 90 points lower than their counterparts who did.

As can be seen in Table 21, the proportion of Māori 15-year-olds not taking science at school was greater than that in the three other ethnic groupings. Almost one in five Māori students reported they did not take science, and the mean score of these students was more than 60 points lower than those who did take science. The mean performance of the Māori students who did take science was not statistically different from the OECD mean. This finding suggests that the very low mean score of the 18 percent of Māori students who did not take science contributed to the relatively overall weaker science mean achievement of Māori.

These findings could be taken to imply that New Zealand's PISA performance in science would improve if more students (not just Māori students) took science.[26] However, it should be noted that those who opt *not* to take science are probably those with the least interest in and aptitude for science, so while their scores might increase if they were compelled to study science, they may still be below average.

Students' educational aspirations

Students were also asked in the questionnaire to indicate the educational qualifications they expected to complete (Table 22). Around five out of six 15-year-olds (84.2%) indicated they expected to complete a post-secondary qualification of some kind. Only a very small proportion of students reported that they did not expect to complete any of the educational qualifications listed. The mean science performance of these students was more than 80 points below the OECD mean of 500, and more than 100 points lower than the average for New Zealand students overall.

Just over one-half of New Zealand's 15-year-olds indicated they expected to complete the highest qualification (a degree or higher), and these students, on average, performed very strongly in science: 35 points higher than the average for all New Zealand students. Not surprisingly, the higher the students' educational aspiration, the higher the mean science performance.

Table 22: Mean scores, by the highest educational qualification expected

Educational qualifications	Percentage of students	Standard error	Mean score	Standard error
No qualifications	1.5	(0.2)	417	(16.8)
NCEA 1	5.5	(0.4)	438	(5.3)
NCEA 2 or 3	8.7	(0.5)	497	(5.5)
A trade, national or tertiary certificate (eg, an apprenticeship)	17.0	(0.7)	506	(3.1)
A diploma (eg, teaching, nursing, business studies, etc. postgraduate diplomas not included)	14.7	(0.5)	521	(4.4)
A degree or higher (eg, Bachelor of Arts/Science/Nursing/Education, etc.)	52.5	(1.0)	565	(3.1)

Note: NCEA is an acronym for National Certificate of Educational Achievement.

26 In Finland, 98 percent of students were taking compulsory science courses, which could help to explain why they had fewer low attainers than New Zealand.

School climate

In the PISA 2000 and 2003 administrations, students were asked to respond to a series of statements concerning teacher-student relationships and students' sense of belonging to school. These questions were not included internationally in PISA 2006, but PISA allows countries to include a small number of additional questions in the student questionnaires. In New Zealand's administration of PISA 2006, questions relating to school climate were included as a national option to reflect the Ministry of Education's priority to focus on student engagement and participation. It is important to note, therefore, that there are no international comparisons for these factors.

As Table 23 shows, around 90 percent of New Zealand's 15-year-olds responded positively to the statements that asked about their sense of belonging to school. On average, these students achieved a significantly stronger science performance than those who did not. The largest average difference in achievement was observed on the statement that asked students whether they *felt awkward and out of place* (48 points), followed by *I feel like an outsider (or left out of things)* (44 points).

Table 23: Mean scores, by school climate

			Strongly agreed or agreed		Strongly disagreed or disagreed	
Statement on school climate	**Percentage of students**	**Standard error**	**Mean score**	**Standard error**	**Mean score**	**Standard error**
Sense of belonging to school						
I [do not] feel like an outsider (or left out of things)	91.5	(0.5)	538	(2.5)	494	(7.3)
I make friends easily	91.3	(0.4)	553	(5.7)	532	(2.6)
I feel like I belong	87.5	(0.6)	536	(2.7)	526	(4.3)
I [I do not] feel awkward and out of place	87.6	(0.5)	541	(2.6)	493	(6.3)
Other students seem to like me	93.6	(0.4)	536	(2.6)	521	(6.6)
I [do not] feel lonely	92.9	(0.5)	536	(2.5)	515	(9.0)
Teacher-student relationship						
Students get along well with most teachers	77.8	(0.8)	539	(2.7)	517	(3.9)
Most teachers are interested in students' well being	82.5	(0.7)	537	(2.7)	517	(3.8)
Most of my teachers really listen to what I have to say	74.1	(0.8)	540	(2.7)	517	(3.1)
If I need extra help, I will receive it from my teachers	85.3	(0.6)	539	(2.5)	505	(4.8)
Most of my teachers treat me fairly	86.5	(0.6)	539	(2.6)	499	(4.5)

Note: For the purposes of this table, statements 1, 4 and 6 have been recoded to positive indexes.

The majority of students also responded positively to the statements that asked them about teacher-student relationships. More than 80 percent of students reported that *teachers provided them with extra help* when they needed it, *treated them fairly* and were *interested in students' well being*. On the other hand, around one-quarter of the students did not agree that *students get along well with most teachers*, and that *most teachers really listened* to what they said.

As Table 23 shows, the mean science achievement of those who responded positively to these statements about teacher-student relationships was significantly stronger. Conversely, the science performance of students who indicated a level of disaffection on teacher-student relationships and school climate was significantly lower than the performance of those who did not.

Ability grouping

Principals were asked to indicate the extent to which ability grouping was used within their schools. In New Zealand a large majority of students (91.0%) were in schools where principals reported that ability grouping was used for *some* subjects. This was the most common approach across PISA countries. Ability grouping in *all* subjects was much less common, particularly among English-speaking and high-performing countries. Interestingly, 50 percent of 15-year-olds in Finland were in schools where there was no ability grouping at all.

Principals were not asked whether ability grouping was used in science, and analysis indicated no significant link between general grouping policies and scientific literacy achievement.

Teachers and resources

Compared with the OECD average, New Zealand students were more likely to be in schools where vacancies in science teaching occurred, but these vacancies were more likely to be filled. In schools where the impact of teacher shortages was perceived to be greater, New Zealand students' achievement was significantly lower than in schools where it was not seen as a problem. Similarly, there was an association between achievement and principals' perceptions of the quality of schools' educational resources. Students in New Zealand schools with the highest perceived quality of resources had the highest science literacy scores. It is worth noting that, on average, the perceived quality of educational resources was 30 points higher than that of the OECD.

Time spent on science

Two-thirds of New Zealand students (64.8%) indicated that they spent 4 hours a week or more on school science lessons. This figure was comparable to the United Kingdom (61.9%) but more than double that of Finland (27.1%) and the OECD average (28.7%). One in six (16.5%) said they spent less than 2 hours a week on regular lessons, or half of the OECD average (32.7%). OECD analysis (OECD forthcoming, b) estimates that New Zealand students were spending an average of 4.06 hours on science, second only to the United Kingdom (4.25 hours) but closely followed by Canada (4.00). It also indicates a strong relationship between time spent studying science and achievement in science literacy: across all OECD countries, students spending more than 4 hours on science scored almost 80 points above those reporting less than 2 hours of science lessons. Even after controlling for socio-economic background, the difference was still 66 score points. For New Zealand students, the differences were even more striking: 113 score points, and still 94 when socio-economic background was taken into account. There was also an association between time spent on science and interest in science topics, although the association was weaker than the OECD average for New Zealand students.

Parents' views of school quality

Sixteen of the PISA 2006 countries, including New Zealand, administered questionnaires to parents of participating students. They were asked to indicate the extent of their agreement with statements about the quality of their child's school. Parents who were satisfied with the school generally had children with higher achievement than parents who were not satisfied. It should be noted, however, that this association does not imply a causal link. It could be the case that parents were satisfied with schools because their children had achieved success there, rather than vice versa.

Summary and issues for consideration

Below we summarise the findings from the analysis of the PISA 2006 results for New Zealand and suggest issues for further consideration. Before doing so, there are three important caveats to bear in mind.

First, the statistics quoted provide only a general picture of average levels of achievement. For example, if girls perform better than boys on one particular measure, it does not mean that all girls perform better than all boys – there will be high achievers among boys as well as girls. Second, many of the factors cited are inter-related; for example, there is an obvious link between parents' education and socio-economic status. It may therefore be that an apparently strong influence on achievement is less strong when other factors are taken into account. Finally, it is important to bear in mind that associations do not necessarily imply causality in either direction. For example, students who take part in more science activities may obtain better science literacy scores: it could be that what they have learned in these activities has helped them to achieve, but it could also be that they choose to take part in these activities because they already have a strong ability in science.

Overall performance

New Zealand students performed very well in PISA 2006, showing that they are well equipped to meet the challenges of the 21st century. Their average score on the combined scientific literacy scale was well above the OECD mean; indeed, only one OECD country (Finland) and one partner country (Hong-Kong-China) had a significantly higher average. New Zealand's science result was significantly better than 46 of the other PISA countries, including the United Kingdom and the United States.

Closer inspection reveals that, at the top of the scale, New Zealand's students were as successful as their Finnish counterparts. However, New Zealand had a larger proportion at the low end of the scale, which explains why their overall average was lower than Finland's. Indeed, New Zealand had one of the widest ranges of scores of any OECD country, while Finland had the smallest.

Why is this? There were some differences between schools: students from large, urban and high-decile schools tended to have higher scientific literacy scores than their counterparts in other school types, as did students from schools where the perceived quality of school resources was good. On the other hand, students from schools where principals reported that science teacher shortages hindered instruction obtained lower scores than students from schools where this was seen as less of a problem.

However, the variation between New Zealand schools was relatively small; most of the variation in student achievement was within schools, and it is therefore necessary to look at other factors that could influence results.

Gender and ethnicity

In terms of overall performance there was no significant difference between New Zealand girls and boys, although boys were slightly more likely to be at the top or bottom of the scale. As noted earlier, high- and low-performing students could be found in all ethnic groups, but there were very clear differences, on average, in the performance of students from the four main ethnic groupings. Pākehā/European students obtained the highest scores, followed by Asian, Māori and Pasifika students, in that order. There was a difference of 100 points between the highest- and lowest-scoring ethnic groups. The difference between Pākehā/European and Asian students was smaller than the other differences, but still statistically significant. There were similarly striking differences in the proportion of students achieving each of the six proficiency levels. The proportion of Asian students reaching the highest levels was similar to that of Pākehā/European, but there was a higher proportion of Asian students at the lowest levels.

Family background

Science achievement in New Zealand was strongly influenced by students' socio-economic background. This relationship was observed across all PISA countries, but in New Zealand it was stronger than the OECD mean. The difference in the mean scores of students in the highest and lowest socio-economic groups was over 100 points. There is a link between socio-economic status and ethnicity (Pākehā/European students were over-represented in the highest group, Māori and Pasifika students in the lowest), but the relationship between achievement and socio-economic status was also strong within each ethnic grouping.

First-generation students (students and parents born outside New Zealand) performed almost as well as their 'native' counterparts (although the difference was not statistically significant), but the performance of second-generation students (students born in New Zealand whose parents were born elsewhere) was significantly weaker. This finding – unique to New Zealand among OECD countries – can be explained with reference to the ethnic composition of the two immigrant groups. Students who spoke English at home, on average, achieved significantly higher scores. This was particularly marked for Pasifika: 20 percent of their student population did not speak English at home, and their science performance was almost 100 score points below the OECD mean.

Several other family background factors were linked with science literacy achievement. There was a strong relationship with level of parental education: on average, the higher a parent's level of education, the higher the student's score. Students who had access to educational resources performed better than those who did not. Students from single-parent families and those who had changed school frequently were likely to perform less well. These factors are inter-related and linked with socio-economic status.

School factors

Most New Zealand PISA students were in Year 11, but there were a few in Year 10 or Year 12. Not surprisingly, there was a strong relationship: the higher the year group, the higher the mean score.

Ninety percent of the PISA students were taking a compulsory and/or optional science course, and they scored, on average, more than 80 points higher than those who were not. There was a significant difference between science and non-science students among boys and girls, and in all ethnic groupings.

The strongest relationship measured was between science literacy scores and educational aspirations. Those with a positive attitude to school in general, and science in particular, achieved higher scores than the disaffected and those with little interest in science.

Aspects of science

New Zealand students performed extremely well on two of the three scientific literacy competencies: *identifying scientific issues* and *using scientific evidence*. They were less strong (though still well above the OECD average) on *explaining phenomena scientifically*. Similarly, New Zealand students performed strongly on two of the assessed science content areas (*living systems* and *earth and space systems*) but were relatively weak (though still above the

OECD average) on the third (*physical systems*). They achieved high scores on the *knowledge about science* scale.

On *identifying scientific issues*, New Zealand girls obtained significantly higher scores than New Zealand boys (other OECD countries showed a similar gender difference on this scale). Girls also scored higher on *using scientific evidence*, but this difference was not statistically significant. Boys scored significantly higher on *explaining phenomena scientifically*. New Zealand boys were stronger on *earth and space systems* and *physical systems*, but there was no gender difference on *living systems*.

Attitudes to science

New Zealand students were lower on interest and similar to, or slightly above, the OECD mean in terms of enjoyment and motivation. They were below the OECD mean in terms of self-concept, meaning that their confidence in learning and understanding science was relatively low, although this was also true of some other high-performing countries. On the self-efficacy scale that measured students' belief in their ability to perform specific scientific tasks, their average score was the same as the OECD mean.

On value beliefs regarding science, New Zealand' students were below the OECD mean for general value but above for personal value. On environmental issues, New Zealand students were below the OECD mean in terms of awareness, concern, optimism and responsibility for sustainable development. Students tended to know less, and be less concerned, about issues such as acid rain and nuclear waste, which have less immediate relevance in a country like New Zealand.

New Zealand boys reported enjoying science to a greater extent than girls did. This may relate to the fact that they had greater confidence in their own ability in science (although this was not justified by PISA test results, since girls performed as well as boys). Boys were more aware of environmental issues, but girls indicated greater concern for the environment and greater responsibility for sustainable development, although they were less optimistic about solving environmental problems.

Asian students had consistently the most positive views on engagement with science. Of the four ethnic groupings, they expressed the greatest interest, enjoyment and general motivation. They also had the highest confidence in their own abilities. They were more likely to be involved in science-related leisure activities, to wish to pursue scientific studies or careers, and to regard advances in science as useful and important. On some, but not all, of these measures, Māori students demonstrated the lowest level of engagement with science. Pasifika students tended to have a more positive attitude to science, although they scored lower than Māori students in the PISA test.

Asian students also reported the highest level of environmental awareness and a greater sense of responsibility for sustainable development, though there was no difference in the level of concern for the environment.

Students from high socio-economic backgrounds had more positive views on engagement with science than those from low socio-economic backgrounds. They indicated a greater level of interest, enjoyment and motivation and higher self-belief in their abilities with reference to science. They were more likely to be involved in science-related leisure activities, and to regard advances in science as useful and important. They indicated a higher level of environmental awareness and a greater sense of responsibility for sustainable development. However, there was no difference in the level of concern for the environment, and students in the high socio-economic category were less likely to be optimistic about solving environmental problems (possibly because greater awareness means a greater recognition of the difficulties involved).

Questions arising

Overall, the science performance of 15-year-old New Zealand students in PISA 2006 was extremely good. In terms of the proportions reaching the highest levels of achievement, New Zealand was second only to Finland (and on some measures virtually equal to Finland) among the OECD countries.

It is of concern, however, that the spread of achievement in New Zealand was so wide – one of the widest of all PISA countries. The level of between-school variation in student performance was comparatively low, so it is not the case that some New Zealand schools are producing students with a high level of scientific literacy while others are failing to do so. Rather, there is a very wide range of student achievement within individual New Zealand schools.

Raising the level of scientific achievement in New Zealand therefore requires a focus on the young people who currently have limited success in this area. To enable them to improve would be beneficial for New Zealand, as scientific literacy is vitally important for the 21st century economy. Reducing the range of student achievement (by raising performance at the lower end of the scale) would also signify a more equitable education system.

A key question, therefore, is how best to help low achievers in science. The PISA findings indicate that students from certain ethnic or socio-economic groups are much less likely to achieve high levels of scientific literacy (although, of course, some of them do), and they could benefit from additional support and encouragement. At the school level, students attending schools where principals reported low-quality resourcing and high science teacher shortages tended to have lower scores, and additional support could be useful in such contexts.

One of the biggest observed differences was between students who were taking science at school (90% of New Zealand students) and those who were not. This raises the question as to whether science should be a compulsory part of the curriculum for Year 11 students in New Zealand. It is of particular concern that almost one in five Māori students were not taking science courses, and research is perhaps needed to investigate the reasons for this. If the performance of non-science students could be raised to equal that of those taking science there would be fewer students at the lower levels of achievement. However, it does not follow that this would happen, as those currently not opting for science are likely to be those with less interest and ability in the subject; making science compulsory would no doubt raise their performance, but not necessarily to very high levels.

In addition to providing an indication of science literacy in an international context, the PISA findings also indicate the relative strengths and weaknesses of New Zealand students in various aspects of science, and this could suggest areas where more attention is needed. Although New Zealand girls achieved above the OECD mean in all three of the science content areas reported separately, their performance in *physical systems* (this content area includes chemistry) was not nearly as good as in the other two areas. (There was comparatively little difference in New Zealand boys' scores.) While this reflects the traditional picture of girls being less interested in physics, the differential in girls' performance across the domains was more marked in New Zealand than in other countries, and is an issue that perhaps needs to be addressed.

There were similar variations in the performance of New Zealand students across the three PISA scientific literacy competencies. In general, it was above the OECD mean on all three, but less strong on *explaining phenomena scientifically*. Girls' scores, in particular, were much lower on this competency. Boys' scores were more consistent, but much lower than girls' scores on *identifying scientific issues*.

Finally, in determining the needs of students and the education system, the factors showing an influence on 15-year-olds' science achievement in this report should not be viewed in isolation, but should be considered alongside all other information available on young people. National Standards, Ka Hikitia, Te Tere Auraki and the Pasifika Education Plan are Ministry of Education strategies that focus on realising the potential of all New Zealand students.

Appendices

Appendix 1 The PISA 2006 sample

In the majority of the 57 countries that participated in PISA 2006 the assessment was administered in schools between 1 March and 31 August 2006.[27] PISA was administered to 4,824 New Zealand students from 170 schools between 24 July and 31 August. A two-stage stratified sampling design was used. First, schools were sampled systematically from a list of every school with the potential to have a 15-year-old enrolled, with probabilities proportional to the number of 15-year-olds in each school. To ensure a representative sample of New Zealand students, schools were selected based on the following characteristics: size, location (urban or rural), decile and authority (private, state or state-integrated). Ninety-two percent of the schools sampled agreed to participate in PISA; schools with the same characteristics as those that declined were approached, and the proportion then rose to 96 percent.

Students participating in PISA were selected with equal probability from a list of all eligible students: those aged from 15 years 3 months to 16 years 2 months at the time of the test (born between 1 May 1990 and 30 April 1991). Sixty students were selected from large schools and up to 30 students from small and medium-sized schools. If a school had fewer than 30 eligible students, all of those students took part.

Special education schools, Māori immersion schools and the Correspondence School were excluded from the school sample.[28] Within the sampled schools, students with an intellectual or physical disability (that would preclude them from performing in a test situation), insufficient English-language experience or who had received most of their instruction in Māori were also eligible for exclusion. If a student was excluded, schools were required to document the exclusion criteria. To ensure good coverage of the 15-year-old school population within all countries, an overall maximum student exclusion rate of less than five percent was required. New Zealand was below the maximum exclusion rate (4.58%). Of the students eligible to participate, 87 percent completed the PISA tests (others were absent from school on the relevant date).

Ethnic composition of the sample

The achieved sample of PISA students broadly mirrored the ethnic composition of 15-year-olds in New Zealand, as shown in Table A1.1.

Table A1.1: Ethnic composition of the PISA sample and the student population

Ethnic grouping	Percentage of 15-year-old school population	Percentage of 15-year-old PISA sample
Pākehā/European	61	62
Māori	19	18
Pasifika	8	7
Asian	8	11
Other ethnicity	2	1
Overseas students	2	~
Total	100	100

Population data source: Ministry of Education, collected July 2006.

Notes: PISA students' ethnicity is based on self-reporting rather than school records.

~ Overseas students were not identified separately in the PISA sample.

Percentages may not add up to 100 due to rounding.

27 For detailed information on PISA Sampling, see OECD 2009a.

28 All students schooled in the home were eligible for exclusion, including 15-year-olds enrolled in the Correspondence School. Māori immersion schools were eligible for exclusion as PISA was not administered in te reo Māori.

In the student questionnaire there were questions used to estimate the socio-economic status of the student's family. Students were then divided into four socio-economic groups of equal size. Table A1.2 shows the ethnic composition of each of these groups. Pākehā/European students were over-represented in the high group and under-represented in the low group; the reverse was true of Māori and Pasifika students. Asian students were more evenly distributed between the socio-economic categories.

Table A1.2: Students from the four ethnic groupings, by socio-economic status

Socio-economic grouping	Pākehā/European		Māori		Pasifika		Asian		Total
	Percentage of students	Std error	Percentage of students	Std error	Percentage of students	Std error	Percentage of students	Std error	Percentage of students
Low	46.7	(2.0)	28.5	(1.7)	14.6	(1.8)	9.0	(0.8)	98.8
Low-medium	64.0	(1.6)	18.6	(1.3)	7.2	(1.0)	9.3	(0.9)	99.1
Medium-high	66.8	(1.6)	14.5	(1.4)	4.5	(0.7)	12.6	(1.1)	98.4
High	73.3	(1.4)	10.2	(1.0)	2.7	(0.4)	12.0	(1.1)	98.2

Notes: Because the proportion of students classified as 'Other' was small (2%) they are not reported. As a result, the percentages do not sum to 100 across the rows.

Standard errors appear in parenthesis

Students were also asked to state whether they or their parents were born in New Zealand. They were defined as 'native' (if they and at least one parent were born here), second-generation (if they were born in New Zealand but their parents were not) or first-generation (if they were born outside New Zealand). Table A1.3 shows the ethnic composition of each immigrant status group.

Table A1.3: Ethnic composition of students, by immigration status

Immigration status	Pākehā/European		Māori		Pasifika		Asian		Total
	Percentage of students	Std error	Percentage of students	Std error	Percentage of students	Std error	Percentage of students	Std error	Percentage of students
Native	71.4	(1.0)	22.6	(1.0)	3.7	(0.4)	1.7	(0.2)	99.4
Second-generation	22.6	(2.5)	2.5	(0.8)	44.7	(3.8)	29.3	(2.7)	99.1
First-generation	35.5	(1.9)	0.0	(0.0)	8.5	(1.2)	49.2	(1.9)	93.2

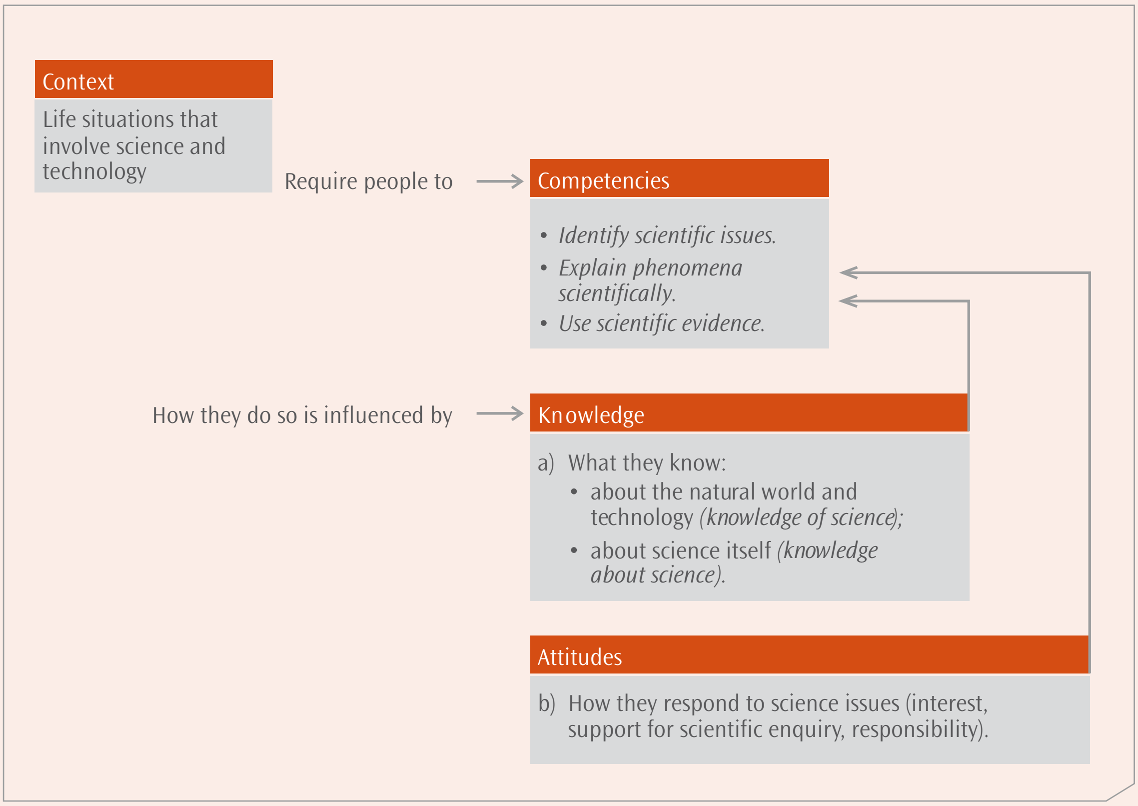
Notes: Because the proportion of students classified as 'Other' was small (2%) they are not reported. As a result the percentages do not sum to 100 across the rows.

Standard errors appear in parenthesis

Appendix 2 The PISA scientific literacy framework

A framework for each literacy area has been developed by a group of international subject experts to ensure the PISA assessment covers the key aspects of a subject or literacy area. The scientific literacy framework used for the two earlier administrations of PISA, when science was a minor domain, has since been further developed and expanded to provide in-depth and robust information on the four inter-related aspects detailed in Figure A2.1. Hence, science trend information will be available from this cycle onwards.

Figure A2.1: The PISA 2006 scientific literacy framework



Source: OECD 2007a, Figure 2.1, p. 35.

Three of the four aspects (contexts, competencies and knowledge) are described briefly in this appendix. The fourth aspect (attitudes) is described in more detail in the PISA 2006 focus report, *Student attitudes to and engagement with science: how ready are our 15-year-olds for tomorrow's world?* (Caygill 2008a).

PISA defines scientific literacy as the extent to which an individual:

- possesses scientific knowledge and uses that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- understands the characteristic features of science as a form of human knowledge and enquiry
- shows awareness of how science and technology shape our material, intellectual, and cultural environments
- engages in science-related issues and with the ideas of science, as a reflective citizen

Scientific literacy contexts

As can be seen in Table A2.1, scientific literacy contexts fall into three major categories – personal, social and global – which are linked to a wide variety of scientific and technological situations.

Table A2.1: PISA 2006 science contexts

	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 infections and 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, natural systems, population growth, sustainable use 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 risks, decisions about housing	Rapid changes (earthquakes, severe weather), slow and progressive changes (coastal erosion, sedimentation), risk assessment	Climate change, impact of modern warfare
Frontiers of 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

Source: OECD 2007a, Figure 2.2, p. 36.

PISA 2006 science competencies

The design of the science test questions required students to demonstrate their capacity to *apply* their scientific knowledge and skills. Therefore, the following scientific competencies were assessed: *identifying scientific issues*, *explaining phenomena scientifically* and *using scientific evidence*.

The New Zealand Curriculum (Ministry of Education 2007) also emphasises the application of knowledge, including the following key science achievement objectives: understanding about science, investigating in science, communicating in science, and participating and contributing. These science skills fall broadly into the three PISA competencies outlined in Table A2.2.

Table A2.2: PISA 2006 scientific competencies

Recognising issues that are possible to investigate scientifically
Identifying keywords to search for scientific information
Recognising the key features of a scientific investigation
Applying knowledge of science in a given situation
Describing or interpreting phenomena scientifically and predicting changes
Identifying appropriate descriptions, explanations and predictions
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

Source: OECD 2007a, Figure 2.3, p. 37.

Knowledge or structure of knowledge

This aspect of the scientific literacy framework covers two knowledge areas: knowledge *of* science and knowledge *about* science.

Knowledge of science: science content areas

The knowledge *of* science domain assesses science content knowledge. The following four content areas were assessed: *physical systems*, *living systems*, *earth and space systems* and *technology systems*. Each content area is described in Table A2.3. Three of these content areas fall broadly into the science strands of the New Zealand Curriculum, and these appear in parentheses in the table.

Table A2.3: Knowledge of science – four content areas

Structure of matter (eg, particle models, bonds)
Properties of matter (eg, changes of state, thermal and electrical conductivity)
Chemical changes of matter (eg, reactions, energy transfer, acids/bases)
Motions and forces (eg, velocity, friction)
Energy and its transformation (eg, conservation, dissipation, chemical reactions)
Interactions of energy and matter (eg, light and radio waves, sound and seismic waves)
Cells (eg, structures and function, DNA, plant and animal)
Humans (eg, health, nutrition, subsystems [ie, digestion, respiration, circulation, excretion and their relationship], disease, reproduction)
Populations (eg, species, evolution, biodiversity, genetic variation)
Ecosystems (eg, food chain, matter and energy flow)
Biosphere (eg, ecosystem services, sustainability)
Structure of earth systems (eg, lithosphere, atmosphere, hydrosphere)
Energy in earth systems (eg, sources, global climate)
Change in earth systems (eg, plate tectonics, geochemical cycles, constructive and destructive forces)
Earth's history (eg, fossils, origin and evolution)
Earth and space (eg, gravity, solar systems)
Role of science-based technologies (eg, solve problems, help humans meet needs and wants, design and conduct investigations)
Relationships between science and technology (eg, technologies contribute to scientific advancement)
Concepts (eg, optimisation, trade offs, cost, risk, benefit)
Important principles (eg, criteria, constraints, innovation, invention, problem solving)

Source: OECD 2007a, Figure 2.4, p. 38.

Knowledge about science: scientific enquiry and scientific explanation

The *knowledge about science* domain assessed students' knowledge of *scientific enquiry* (knowledge of the different scientific disciplines and the nature of the world) and *scientific explanations* (form of human enquiry). Details are provided in Table A2.4.

Table A2.4: Knowledge about science: scientific enquiry and explanations

Origin (eg, curiosity, scientific questions)
Purpose (eg, to produce evidence that helps answer scientific questions, such as current ideas, models and theories to guide enquiries)
Experiments (eg, different questions suggest different scientific investigations, design)
Data (eg, quantitative [measurements], qualitative [observations])
Measurement (eg, inherent uncertainty, replicability, variation, accuracy/precision in equipmentand procedures)
Characteristics of results (eg, empirical, tentative, testable, falsifiable, self-correcting)
Types (eg, hypothesis, theory, model, scientific law)
Formation (eg, existing knowledge and new evidence, creativity and imagination, logic)
Rules (eg, logically consistent, based on evidence, based on historical and current knowledge)
Outcomes (eg, new knowledge, new methods, new technologies, new investigations)

Source: OECD 2007a, Figure 2.5, p. 39.

In short, PISA is designed to assess students' content knowledge, but at the same time requires students to go beyond simply reproducing knowledge gained from specific curricula: students are required to *apply* their knowledge and skills.

Appendix 3 Test booklets and questions

Students each completed one of the 13 two-hour test booklets. To complete the entire PISA 2006 assessment (all of the questions designed) would require six and a half hours of testing time: 210 minutes for science (main focus), 60 minutes for reading and 120 minutes for mathematics. Only two hours were allowed for the testing sessions, so each test booklet contained four clusters of questions that were rotated in combinations.

This approach had a number of advantages: (i) more questions were used than would have been possible if every student had completed the same booklet; (ii) a representative sample of students responded to each cluster of questions; (iii) each cluster appeared in four possible positions in the booklet, and therefore it was possible to measure test fatigue (student disengagement with questions placed towards the end of the test).

The assessment included five types of questions: multiple choice, complex multiple choice, closed-constructed, open-constructed and short-response questions. The questions covered the dimensions of the scientific, reading and mathematical literacy frameworks. Table A3.1 shows the distribution of the PISA science questions by question type (short-response questions were not asked in science) and the elements of the scientific literacy framework covered.

Table A3.1: Distribution of questions by the PISA scientific literacy framework

Context	Number of items	Number of multiple-choice questions	Number of complex multiple-choice questions	Number of closed-constructed response questions	Number of open-constructed response questions
Physical systems	17	8	3	2	4
Living systems	25	9	7	1	8
Earth and space	12	5	2	1	4
Technology systems	8	2	3	0	3
Scientific enquiry	25	9	10	0	6
Scientific explanations	21	5	4	1	11
Identifying scientific issues	24	9	10	0	5
Explaining phenomena scientifically	53	22	11	4	16
Using scientific evidence	31	7	8	1	15
Personal	29	13	6	4	6
Social	59	21	16	0	22
Global	20	4	7	1	8

Source: OECD 2007a, Figure A5.1, p. 364.

When a subject is the main focus of PISA, a large pool of new questions is required. To prepare for this, the PISA Consortium, led by the Australian Council for Educational Research (ACER), established five test development teams in well-known and culturally diverse institutions.[29] In addition, to ensure the test questions were also culturally and contextually diverse, participating PISA countries were encouraged to submit questions; 21 countries submitted science questions for PISA 2006, including New Zealand.[30]

After the questions had undergone further testing and development, countries were invited to review and rate them in terms of their suitability for the PISA assessment.[31] Countries were provided with guidelines and criteria for rating, such as relevance to preparedness for life, the authenticity of the question context and how much interest the question held for 15-year-olds. The science questions selected to go forward to the main study were evaluated again at the country level and tested by the Consortium using Item Response Theory. New Zealand also contributed to the review of the test questions. The PISA Steering Group members, science experts, item writers and education sector union representatives attended a workshop in August 2005 to review the PISA science questions.

Appendix 4 Sample questions and scoring

Two science questions recently published in the OECD (2009c) report *Take the test*: *sample questions from OECD's PISA assessment* are shown on the following pages: 'Greenhouse' and 'Acid rain'. 'Greenhouse' includes examples of some difficult questions and 'Acid rain' includes some examples of easy questions. The scoring guide, difficulty level, science competency and percentage of students that answered the question correctly across the OECD are also shown. The percentage of correct answers in each participating country (including New Zealand) can be found in Table A4.1.

29 ACER (Australia); CITO (the Netherlands); ILS (University of Oslo, Norway); IPN (University of Kiel, Germany); and NIER (Japan).

30 After undergoing further development by the consortium's experts, New Zealand's contribution was included in the PISA 2006 main study.

31 For further details on the development and testing phase of the PISA science questions, see OECD 2009a pp. 29–35.

SCIENCE UNIT 5: 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.

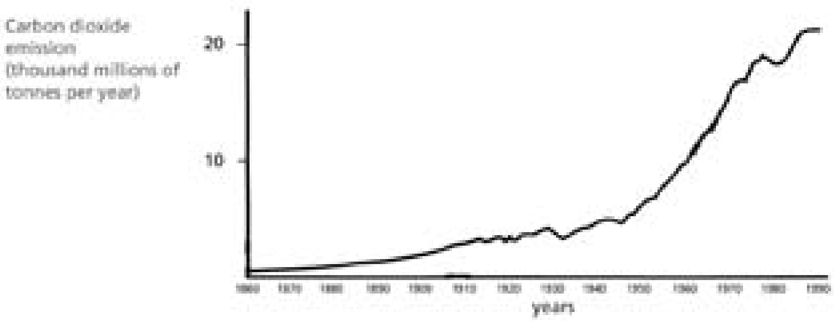
As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term *greenhouse effect*.

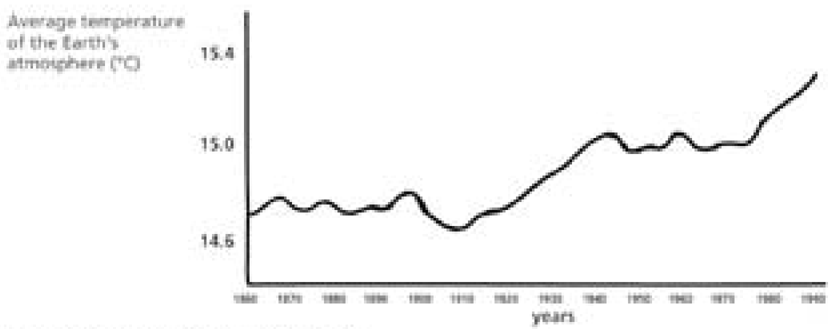
The greenhouse effect is said to have become more pronounced during the twentieth century.

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.





Source: CSTI Environmental Information Paper 1, 1992.

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.

OECD (2009): Take the Test: Sample Questions from PISA Assessments, p.199. Paris: OECD.

QUESTION 5.1

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

....

....

QUESTION 5.2

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.

....

....

....

QUESTION 5.3

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.

....

....

GREENHOUSE SCORING 5.1

Full credit:

- Responses that refer 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.
- Responses that refer (in general terms) to a positive relationship between temperature and carbon dioxide emission.
  - The amount of CO2 and average temperature of the Earth is directly proportional.
  - They have a similar shape indicating a relationship.

OECD (2009): Take the Test: Sample Questions from PISA Assessments, pp. 262-266. Paris: OECD.

No credit:

- Responses that refer 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.
- Responses that refer 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.
- 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.
- Missing.

Answering this question correctly corresponds to a difficulty of 529 score points on the PISA 2006 science scale. Across OECD countries, 54% of students answered correctly. This question assesses students' competencies in using scientific evidence.

GREENHOUSE SCORING 5.2

Full credit: Responses that refer to one particular part of the graphs in which the curves are not both descending or both climbing and gives the corresponding explanation, such as:

- 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.

OECD (2009): Take the Test: Sample Questions from PISA Assessments, pp. 262-266. Paris: OECD.

Partial credit:

- Responses that mention a correct period, without any explanation.

- Responses that mention only one particular year (not a period of time), with an acceptable explanation.

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

- Responses that give 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.

- Responses that refer 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.

- Responses that refer 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.

- Responses that indicate difference in the graphs, but explanation is poor.

  - In the 1940's the heat was very high but the carbon dioxide very low.

No credit:

- Responses that refer 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.

- Responses that refer to a poorly defined period or year without any explanation.

  - The middle part.
  - 1910.

- Other responses.

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

OECD (2009): Take the Test: Sample Questions from PISA Assessments, pp. 262-266. Paris: OECD.

-Missing.

Answering this question correctly corresponds to a difficulty of 659 score points on the PISA 2006 science scale. Giving a partially correct answer corresponds to a difficulty of 568 score points on the PISA 2000 science scale. Across OECD countries, 35% of students answered correctly. The question assesses students' competencies in using scientific evidence.

GREENHOUSE SCORING 5.3

Full credit:

- Responses that give a factor referring to the energy/radiation coming from the Sun.

  - The sun heating and maybe the earth changing position.
  - Energy reflected back from Earth. *[Assuming that by "Earth" the student means "the ground".]*

- Responses that give a factor referring to a natural component or a potential pollutant.

  - Water vapour in the air.
  - Clouds.
  - The things such as volcanic eruptions.
  - Atmospheric pollution (gas, fuel).
  - The amount of exhaust gas.
  - CFC's.
  - The number of cars.
  - Ozone (as a component of air).

No credit:

- Responses that refer to a cause that influences the carbon dioxide concentration.

  - Clearing of rain forest.
  - The amount of CO_2 being let off.
  - Fossil fuels.

- Responses that refer to a non-specific factor.

  - Fertilisers.
  - Sprays.
  - How the weather has been.

- Other incorrect factors or other responses.

  - Amount of oxygen.
  - Nitrogen.
  - The hole in the ozone layer is also getting bigger.

- Missing.

Answering this question correctly corresponds to a difficulty of 709 score points on the PISA 2006 science scale. Across OECD countries, 19% of students answered correctly. The question assesses students' competencies in explaining phenomena scientifically.

OECD (2009): Take the Test: Sample Questions from PISA Assessments, pp. 262-266. Paris: OECD.

SCIENCE UNIT 10: 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.

QUESTION 10.1

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 sulfur oxides and nitrogen oxides as well.

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

....

....

The effect of acid rain on marble can be modelled by placing chips of marble in vinegar overnight. Vinegar and acid rain have about the same acidity level. When a marble chip is placed in vinegar, bubbles of gas form. The mass of the dry marble chip can be found before and after the experiment.

QUESTION 10.2

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

QUESTION 10.3

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

Explain why the students included this step in their experiment.

....

....

OECD (2009): Take the Test: Sample Questions from PISA Assessments, p. 209. Paris: OECD.

ACID RAIN SCORING 10.1

Full credit:

- Responses that mention 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.
  - They come from the burning of materials that contain sulfur and nitrogen.
- 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.
- 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.
  - 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.]*

Answering this question correctly corresponds to a difficulty of 709 score points on the PISA 2006 science scale. Across OECD countries, 19% of students answered correctly. The question assesses students' competencies in explaining phenomena scientifically.

OECD (2009): Take the Test: Sample Questions from PISA Assessments, pp. 269-270. Paris: OECD.

ACID RAIN SCORING 10.2

Full credit: A. Less than 2.0 grams

No credit: Other responses and missing.

Answering this question correctly corresponds to a difficulty of 460 score points on the PISA 2006 science scale. Across OECD countries, 67% of students answered correctly. This question assesses students' competencies in using scientific evidence.

ACID RAIN SCORING 10.3

Full credit: Responses such as:

- To 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: Responses which compare with the test of vinegar and marble, but do not make 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 and missing.

Answering this question correctly corresponds to a difficulty of 717 score points on the PISA 2006 science scale. Giving a partially correct answer corresponds to a difficulty of 513 score points on the PISA 2000 science scale. Across OECD countries, 36% of students answered correctly. The question assesses students' competencies in identifying scientific issues.

OECD (2009): Take the Test: Sample Questions from PISA Assessments, pp. 269-270. Paris: OECD.

Table A4.1: Percentage correct for each country on ‘Greenhouse’ and ‘Acid rain’

	UNIT:	5 : Greenhouse			10 : Acid Rain		
	QUESTION:	5.1 %	5.2 %	5.3 %	10.1 %	10.2 %	10.3 %
OECD countries	Australia	67	44	21	58	71	45
	Austria	46	28	17	72	65	38
	Belgium	57	40	20	65	67	39
	Canada	70	44	22	69	73	45
	Czech Republic	50	32	21	63	75	34
	Denmark	56	35	15	52	60	37
	Finland	67	48	32	73	78	38
	France	64	44	19	43	65	39
	Germany	52	37	22	69	69	37
	Greece	48	33	25	59	67	33
	Hungary	50	31	17	69	72	27
	Iceland	59	33	11	54	59	38
	Ireland	59	37	19	70	68	46
	Italy	40	27	14	49	61	33
	Japan	69	54	18	54	83	35
	Korea	64	49	18	60	84	36
	Luxembourg	45	25	11	54	59	32
	Mexico	16	14	16	44	48	18
	Netherlands	60	42	34	70	70	42
	New Zealand	63	37	20	58	73	47
	Norway	53	29	15	54	53	32
	Poland	43	32	16	65	64	36
	Portugal	52	28	18	49	64	32
	Slovak Republic	40	27	16	51	69	34
	Spain	60	35	22	51	63	25
	Sweden	55	30	17	55	67	39
	Switzerland	54	38	23	60	67	35
	Turkey	40	19	9	26	51	20
	United Kingdom	65	36	20	61	70	39
	United States	54	29	18	54	66	35
	OECD average	**54**	**34**	**19**	**58**	**67**	**36**
Partners	Argentina	35	20	8	34	55	15
	Azerbaijan	17	11	5	30	45	11
	Brazil	34	18	16	33	44	17
	Bulgaria	29	20	14	37	60	22
	Chile	41	23	9	38	57	32
	Chinese Taipei	65	52	29	69	81	38
	Colombia	16	14	15	34	52	28
	Croatia	43	32	18	62	70	39
	Estonia	66	44	30	68	78	42
	Hong Kong- China	75	53	31	73	79	43
	Indonesia	28	17	15	14	49	13
	Israel	44	32	21	41	51	35
	Jordan	27	16	13	50	54	30
	Kyrgyzstan	11	4	3	15	41	11
	Latvia	55	38	22	62	78	37
	Liechtenstein	58	40	26	68	63	34
	Lithuania	49	30	20	52	74	37
	Macao-China	61	43	21	56	74	29
	Montenegro	36	10	6	40	56	19
	Qatar	13	6	7	21	35	8
	Romania	27	20	15	38	52	19
	Russian Federation	49	33	20	47	74	34
	Serbia	23	16	8	37	65	24
	Slovenia	42	36	23	70	77	43
	Thailand	22	12	11	23	57	24
	Tunisia	38	17	12	28	45	21
	Uruguay	45	23	12	40	53	27

OECD (2009): *Take the Test: Sample Questions from PISA Assessments, pp. 305-306.* Paris: OECD.

Appendix 5 PISA proficiency levels

To make the results more meaningful, PISA assigns students to one of six proficiency levels. The proficiency levels provide an overview of the spread of student performance, and at the same time link student performance to competencies by describing the types of tasks that students at each level should typically be expected to do (Figure A5.1). Student proficiency levels are reported on the overall science scale and on the three science competencies scales. This type of analysis is made possible by the use of item response modelling.[32]

The proficiency levels represent a range from the highest scores (mean 707 or greater) to the lowest (mean less than 408). Students are assigned to the highest level for which they would be expected to answer at least 50 percent of the questions correctly. For example, students reaching Level 4 would be expected to be proficient at the majority of tasks assigned to Levels 1 through to 4. The proportion of Level 4 students answering a Level 4 question correctly would be at least 50 percent; the proportion of Level 5 students doing so would be higher, and the proportion of Level 3 students lower. This relationship is shown diagrammatically in Figure A5.2.

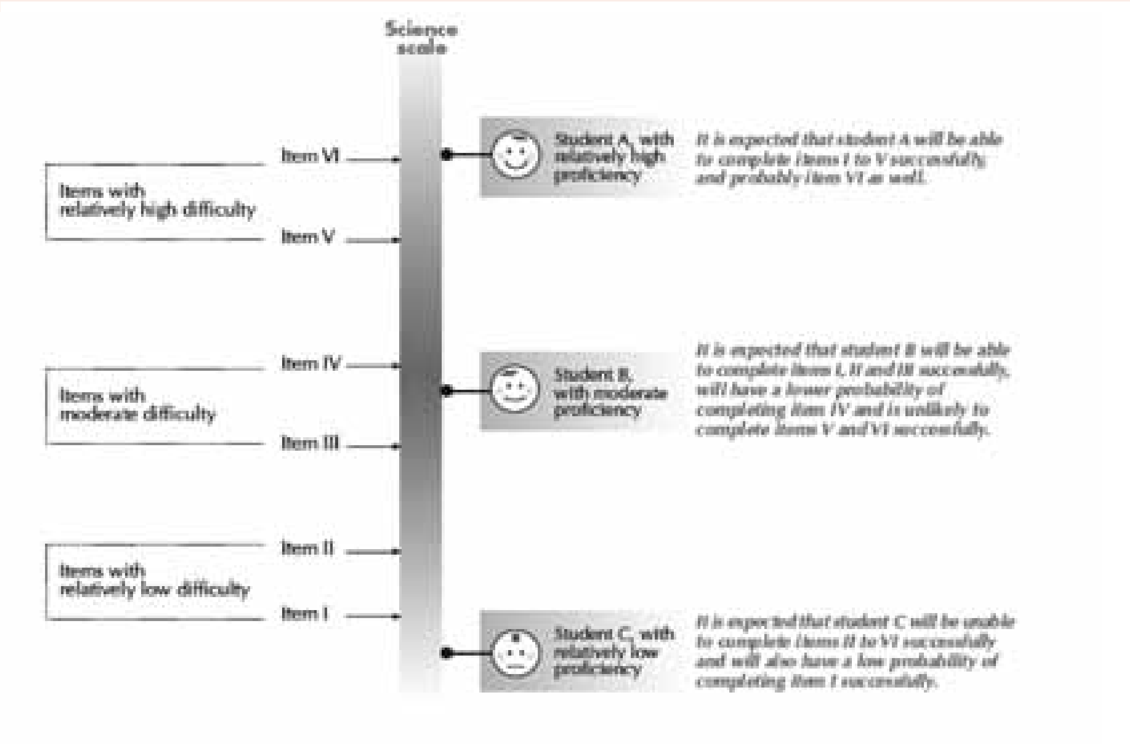
32 See OECD 2009b for further information.

Figure A5.1: What the scientific literacy proficiency levels measure

Level		
707.9	1.3% of students across the OECD can perform tasks at Level 6 on the science scale	At Level 6, students can consistently identify, explain and apply scientific knowledge and *knowledge about science* in a variety of complex life situations. They can link different information sources and explanations and use evidence from those sources to justify decisions. They clearly and consistently demonstrate advanced scientific thinking and reasoning, and they demonstrate willingness to use their scientific understanding in support of solutions to unfamiliar scientific and technological situations. Students at this level can use scientific knowledge and develop arguments in support of recommendations and decisions that centre on personal, social or global situations.
633.3	9.0% of students across the OECD can perform tasks at least at Level 5 on the science scale	At Level 5, students can identify the scientific components of many complex life situations, apply both scientific concepts and *knowledge about science* to these situations, and can compare, select and evaluate appropriate scientific evidence for responding to life situations. Students at this level can use well-developed inquiry abilities, link knowledge appropriately and bring critical insights to situations. They can construct explanations based on evidence and arguments based on their critical analysis.
558.7	29.3% of students across the OECD can perform tasks at least at Level 4 on the science scale	At Level 4, students can work effectively with situations and issues that may involve explicit phenomena requiring them to make inferences about the role of science or technology. They can select and integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations. Students at this level can reflect on their actions and they can communicate decisions using scientific knowledge and evidence.
484.1	56.7% of students across the OECD can perform tasks at least at Level 3 on the science scale	At Level 3, students can identify clearly described scientific issues in a range of contexts. They can select facts and knowledge to explain phenomena and apply simple models or inquiry strategies. Students at this level can interpret and use scientific concepts from different disciplines and can apply them directly. They can develop short statements using facts and make decisions based on scientific knowledge.
409.5	80.8% of students across the OECD can perform tasks at least at Level 2 on the science scale	At Level 2, students have adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving.
334.9	94.8% of students across the OECD can perform tasks at least at Level 1 on the science scale	At Level 1, students have such a limited scientific knowledge that it can only be applied to a few, familiar situations. They can present scientific explanations that are obvious and that follow explicitly from given evidence.

Source: OECD 2007a, p. 43.

Figure A5.2: The relationship between questions and students on a proficiency scale



Source: OECD 2007a, Figure 2.7, p. 41.

It is important to note that when reporting the percentage of students achieving a particular level or higher, the proportion is cumulative. For example, the proportion of students achieving at least Level 4 would include those assessed at Level 5 and Level 6.

Appendix 6 Student attitudes indices

General interest in science: derived from students' level of interest in learning the following topics: *i)* topics in physics; *ii)* topics in chemistry; *iii)* the biology of plants; *iv)* human biology; *v)* topics in astronomy; *vi)* topics in geology; *vii)* ways scientists design experiments; and viii) what is required for scientific explanations.

Enjoyment of science: derived from students' level of agreement with the following statements: *i)* I generally have fun when I am learning science topics; *ii)* I like reading about science; *iii)* I am happy doing science problems; *iv)* I enjoy acquiring new knowledge in science; and *v)* I am interested in learning about science. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

General value of science: derived from students' level of agreement with the following statements: *i)* advances in science and technology usually improve people's living conditions; *ii)* science is important for helping us to understand the natural world; *iii)* advances in science and technology usually help improve the economy; *iv)* science is valuable to society; and *v)* advances in science and technology usually bring social benefits. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

Personal value of science: derived from students' level of agreement with the following statements: *i)* some concepts in science help me see how I relate to other people; *ii)* I will use science in many ways when I am an adult; *iii)* science is very relevant to me; *iv)* I find that science helps me to understand the things around me; *v)* when I leave school there will be many opportunities for me to use science; and *vi)* some concepts in science help me see how I relate to other people. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

Science-related activities: derived from the frequency with which students did the following things: *i)* watch TV programmes about science; *ii)* borrow or buy books on science topics; *iii)* visit web sites about science topics; *iv)* listen to radio programmes about advances in science; *v)* read science magazines or science articles in newspapers; and *vi)* attend a science club. A four-point scale with the response categories 'very often', 'regularly', 'sometimes' and 'never or hardly ever' was used.

Self-efficacy in science: derived from students' beliefs in their ability to perform the following tasks on their own: *i)* recognise the science question that underlies a newspaper report on a health issue; *ii)* explain why earthquakes occur more frequently in some areas than in others; *iii)* describe the role of antibiotics in the treatment of disease; *iv)* identify the science question associated with the disposal of garbage; *v)* predict how changes to an environment will affect the survival of certain species; *vi)* interpret the scientific information provided on the labelling of food items; *vii)* discuss how new evidence can lead you to change your understanding about the possibility of life on Mars; and *viii)* identify the better of two explanations for the formation of acid rain. A four-point scale with the response categories 'I could do this easily', 'I could do this with a bit of effort', 'I would struggle to do this on my own' and 'I couldn't do this' was used.

Self-concept in science: derived from students' level of agreement with the following statements: *i)* learning advanced school science topics would be easy for me; *ii)* I can usually give good answers to test questions on school science topics; *iii)* I learn school science topics quickly; *iv)* school science topics are easy for me; *v)* when I am being taught school science, I can understand the concepts very well; and *vi)* I can easily understand new ideas in school science. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

Instrumental motivation to learn science: derived from students' level of agreement with the following statements: *i)* 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; *ii)* what I learn in my science subject(s) is important for me because I need this for what I want to study later on; *iii)* I study science because I know it is useful for me; *iv)* studying my science subject(s) is worthwhile for me because what I learn will improve my career prospects; and *v)* I will learn many things in my science subject(s) that will help me get a job. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

Future-oriented motivation to learn science: derived from students' level of agreement with the following statements: *i)* I would like to work in a career involving science; *ii)* I would like to study science after secondary school; *iii)* I would like to spend my life doing advanced science; and *iv)* I would like to work on science projects as an adult. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

Awareness of environmental issues: derived from students' beliefs regarding their own level of information on the following environmental issues: *i)* the increase of greenhouse gases in the atmosphere; *ii)* the use of genetically modified organisms (GMO); *iii)* acid rain; *iv)* nuclear waste; and v) the consequences of clearing forests for other land use. A four-point scale with the response 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' was used.

Level of concern for environmental issues: index derived from students' level of concern about the following environmental issues: *i)* air pollution; *ii)* energy shortages; *iii)* extinction of plants and animals; *iv)* clearing of forests for other land use; *v)* water shortages; and vi) nuclear waste. A four-point scale with the response 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' was used. .

Optimism regarding environmental issues: derived from students' optimism concerning the development over the next 20 years of the problems associated with the following environmental issues: *i)* air pollution; *ii)* energy shortages; *iii)* extinction of plants and animals; *iv)* clearing of forests for other land use; *v)* water shortages; and *vi)* nuclear waste. A three-point scale with the response categories 'improve', 'stay about the same' and 'get worse' was used. The items were inverted for scaling and positive values on this new index for PISA 2006 indicate higher levels of students' optimism about environmental issues.

Responsibility for sustainable development: derived from students' level of agreement with the following statements: *i)* it is important to carry out regular checks on the emissions from cars as a condition of their use; *ii)* it disturbs me when energy is wasted through the unnecessary use of electrical appliances; *iii)* I am in favour of having laws that regulate factory emissions even if this would increase the price of products; *iv)* to reduce waste, the use of plastic packaging should be kept to a minimum; v) industries should be required to prove that they safely dispose of dangerous waste materials; *vi)* I am in favour of having laws that protect the habitats of endangered species; and *vii)* electricity should be produced from renewable sources as much as possible, even if this increases the cost. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

School preparation for science-related careers: derived from students' level of agreement with the following statements: *i)* the subjects available at my school provide students with the basic skills and knowledge for a science-related career; *ii)* the science subjects at my school provide students with the basic skills and knowledge for many different careers; *iii)* the subjects I study provide me with the basic skills and knowledge for a science-related career; and *iv)* my teachers equip me with the basic skills and knowledge I need for a science-related career. A four-point scale with the response categories 'strongly agree', 'agree', 'disagree' and 'strongly disagree' was used.

Source: OECD 2007a, pp. 337–341.

Appendix 7 Quality Assurance

To ensure the PISA data are of high quality and fit for purpose, particularly in respect to international comparability, strict technical standards are implemented along with comprehensive quality assurance procedures. These procedures are established through international standardised operational manuals, such as the *National project manager's manual*, *School sampling preparation manual*, *Data management manual* and *Test administrators' manual* (including a standardised script for the administration of the testing session in schools).

National centres were required to record specific project information on a series of forms relating to procedures such as sampling, translation, modifications to test questions, administration of the PISA tests and data management. These had to be submitted to the PISA Consortium for approval prior to verification. For example, a series of sampling forms was provided to Westat (the international centre responsible for the sample) to ensure the sample population was covered, sampling procedures were adhered to, and school and student response rates were met.

A Consortium staff member was appointed to each PISA country to undertake the role of a National Centre PISA Quality Monitor (NCPQM). In each PISA country, PISA Quality Monitors (PQMs) were employed by the Consortium to observe test administrations in a sample of 15 schools.

The NCPQM was responsible for: (i) interviewing the National Project Manager to ensure the strict technical and quality standards had been adhered to; (ii) training the PISA Quality Monitors; and (iii) the selection of schools to be monitored. New Zealand's national centre also conducted quality monitoring of the testing sessions in schools.

To ensure the reliability of the marking of student responses to open-ended test questions, 100 of each of the 13 test booklets were blind marked independently by four markers. The data collected were entered into software specially designed for PISA, which facilitated data entry and data cleaning, and also detected common errors during data entry.

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Definitions and technical notes

Mean

Student performances in PISA are reported using means, which is a type of average, for groupings of students. In general, the mean of a set of scores is the sum of the scores divided by the number of scores, and is often referred to as 'the average'. Note that for PISA, as with other large-scale studies, the means for a country are adjusted slightly (in technical terms 'weighted') to reflect the total population of 15-year-olds rather than just the sample.

Mean achievement scores are reported on *science literacy* overall; on the *knowledge about science*, and *knowledge of science* scales; and on three of the four science content scales: *living systems*, *physical systems* and *earth space and systems*.[33] Mean scores are also reported for the three competency areas: *identifying scientific issues*, *explaining phenomena scientifically* and *using scientific evidence*. Throughout this report, where appropriate, science means presented within the text usually appear in parentheses.

Minimum group size for reporting achievement data

In this report, student achievement data are not reported where the group size is less than 30 students.

OECD mean or average

The OECD mean, sometimes referred to as the OECD average, includes only the OECD countries – no non-OECD (partner) countries are included in this average. The OECD mean is the average of the means for the OECD countries. An OECD mean score of 500 points was constructed for *science literacy* overall, with about two-thirds of students across OECD countries scoring between 400 and 600 points.

Percentile

The percentages of students performing below or above particular points on the scale can be used to describe the range of achievement. The lowest outer limit is the 5th percentile – the score at which only 5 percent of students achieved a lower score – and 95 percent achieved a higher score. The highest outer limit is the 95th percentile – the score at which only 5 percent of students achieved a higher score and 95 percent a lower score; thus 90 percent of the 15-year-old student scores lie between the 5th and 95th percentiles. The difference between the 5th and 95th percentiles provides a measure of the spread of scores.

Proficiency levels

PISA developed proficiency levels to describe the range in literacy across 15-year-old students. The proficiency levels describe the competencies of students achieving at that level and are anchored at certain score points on the achievement scale. Note that students were considered to be proficient at a particular level if, on the basis of their overall performance, they could be expected to answer at least half of the items in that level correctly. Typically, students who were proficient at higher levels had also demonstrated their abilities and knowledge at lower levels. Proficiency levels in science are described in greater detail in Appendix 5.

Scale score points

The design of PISA allows for a large number of questions to be used in mathematics, science and reading, but each student answers only a proportion of these questions. PISA employs techniques to enable population estimates of achievement to be produced for each country even though a sample of students responded to differing selections of questions. These techniques result in scaled scores which are on a scale with a mean of 500 and a standard deviation of 100. When a literacy area is the main focus of a cycle the OECD mean is set at 500 against which performance has since been measured. For example, the reading literacy scale was set at 500 in 2000 when reading was the main focus and when reading was a minor domain in 2006 the OECD mean score was 492.

In 2006 the OECD mean score was set for the overall *science literacy* scale. Other science scales may differ slightly from this value. For example, the OECD mean for *living systems* was 502.

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33 There were insufficient questions for technology systems to allow for analysis at an individual content level. These items were included in the overall Knowledge of Science scale.

Standard error

Because of the technical nature of PISA, the calculation of statistics such as means and proportions has some uncertainty due to (i) generalising from the sample to the total 15-year-old school population, and (ii) inferring each student's proficiency from their performance on a subset of items. The standard errors (usually given in brackets) provide a measure of this uncertainty. In general, we can be 95 percent confident that the true population value lies within an interval 1.96 standard errors either side of the given statistic.

Statistically significant

In order to determine whether a difference between two means is actual, it is usual to undertake tests of significance. These tests take into account the means and the error associated with them. If a result is reported as not being statistically significant, then although the means might be slightly different, we do not have sufficient evidence to infer that they are different. All tests of statistical significance referred to in this report are at the 95 percent confidence level.

Variance and standard deviation

Two common measures of the spread of a distribution are the variance and the standard deviation. As noted earlier, the standard deviation for the OECD of the distribution for the PISA science literacy scale has a value of 100 and has the property that approximately two-thirds (68%) of students scores are expected to be between 400 and 600 scale points (i.e. within one standard deviation of the OECD mean of 500).

For the PISA science literacy scale, both the variance and the standard deviation provide measures of how far, on average, each student's score is from the mean. Because the total sum of the differences between each score and the mean is zero, the variance is calculated by squaring each difference and then an average can be calculated for all of the squared differences. The standard deviation is calculated by taking the square root of the variance. In PISA these measures, calculated from the sample, are weighted (adjusted mathematically) to estimate their values for the total PISA population (all 15-year-olds).

The total amount of variance for a distribution can, in certain circumstances, be separated into components that are associated with other factors (this type of analysis requires the use of more complex statistical models). In this report the amount of variance between schools for the science literacy distribution is an example of such an analysis.

Further information

New Zealand's PISA 2006 web page is at www.educationcounts.govt.nz/goto/pisa. The OECD's PISA 2006 international report can be accessed from the OECD PISA website www.pisa.oecd.org. An interactive data selection facility, which allows selected analyses of international contextual information and student performance, is also available from this site, along with the international versions of the student, school and parent questionnaires.

PISA was administered in New Zealand again during July and August 2009. The PISA 2009 results will be published by the OECD in December 2010.

List of countries participating in PISA 2006

Argentina*	Australia	Austria
Azerbaijan*	Belgium	Brazil*
Bulgaria*	Canada	Chile*
Colombia*	Croatia*	Czech Republic
Denmark	Estonia*	Finland
France	Germany	Greece
Hong Kong-China*	Hungary	Iceland
Indonesia*	Ireland	Israel*
Italy	Japan	Jordan*
Korea	Kyrgyzstan*	Latvia*
Liechtenstein*	Lithuania*	Luxembourg
Macao-China*	Mexico	The Netherlands
New Zealand	Norway	Poland
Portugal	Qatar*	Romania*
Russian Federation*	Serbia & Montenegro*	Slovak Republic
Slovenia*	Spain	Sweden
Switzerland	Chinese Taipei*	Thailand*
Tunisia*	Turkey	United Kingdom
United States	Uruguay*	

* Non-OECD countries

Note: Serbia and Montenegro equal two countries.

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