Ready for Tomorrow's World?

The Competencies of Irish 15-year-olds in PISA 2006

Summary Report

Eemer Eivers
Gerry Shiel
Rachel Cunningham

Prepared for the Department of Education and Science by the Educational Research Centre

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Preface

The Programme for International Student Assessment (PISA) is a project of the Organisation for Economic Co-operation and Development (OECD), designed to assess the scientific, mathematical, and reading literacy skills of 15-year-olds. First conducted in 2000, PISA runs in three-yearly cycles. Science was the focus in 2006, but test data were also gathered on reading and mathematical literacy. Students in 57 countries (including all 30 OECD countries) took part in the assessment, which was implemented in Ireland in March/April 2006.

Several reports based on PISA 2000 and 2003 have been published by the OECD *(www.pisa.oecd.org)*. A number of Irish reports, including the national reports for Ireland for 2000 and 2003 (Shiel, Cosgrove, Sofroniou, & Kelly, 2001; Cosgrove, Shiel, Sofroniou, Zastrutski & Shortt, 2005), are also available *(www.erc.ie/pisa)*. The present report is published at the same time as the OECD's initial report on PISA 2006 (*PISA 2006: Science Competencies for Tomorrow's World*) and is designed for a general audience. It summarises findings for 2006 that are of most relevance to Irish readers, and presents some data based on questions specifically designed for an Irish context that are not in the OECD report. A more in-depth report on the 2006 data from an Irish perspective will be published in 2008.

This report is divided into eight chapters. Chapter 1 provides some background to the study and describes what PISA measures. Chapter 2 provides an overview of country scores on each PISA domain (science, reading, and mathematics), comparing Ireland's performance to the OECD average and to other countries. Chapter 3 provides detail on Ireland's performance on scientific literacy, while Chapter 4 relates the conceptualisation of, and achievement in, science in PISA with that in the Junior Certificate Examination. Chapter 5 details Irish students' performance on the reading and mathematical literacy tests, Chapter 6 describes students' science-related attitudes, and Chapter 7 examines other factors relating to test performance. Chapter 8 summarises the findings and presents some conclusions.

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Thanks are due to staff at the Educational Research Centre, including Thomas Kellaghan, David Millar, John Coyle, Mary Rohan and Hilary Walshe. Thanks also to Carly Cheevers, for her work as a research assistant on PISA until August 2007, and to Eddie McDonnell, who helped to match elements of PISA and the Junior Certificate science syllabus. Finally, we thank all students and schools that participated in the 2006 study, and the preceding field trial in 2005. In particular, we thank the students for completing the test and the questionnaire, and the school co-ordinators, without whose help PISA would not have been possible.

List of Abbreviations

ESCS	Economic, Social and Cultural Status (a measure developed for PISA)
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
rJCSS	Revised Junior Certificate Science Syllabus
SE	Standard error

Statistical Terms Used

Although designed for a general readership, this report contains some statistical terms. These are defined below.

Correlation Correlation coefficients are measures of the relationship between two variables and can range from –1.00 to +1.00. A negative correlation (e.g., –.35) means that as one variable increases, the other decreases; a positive correlation (e.g., .35) means that both either increase or decrease together. A value of 0 indicates no relationship between variables, while the closer a value is to ±1, the stronger the relationship. A high correlation does not necessarily mean that one variable causes the other; the possible influence of other variables should always be considered.

Scale scores PISA uses a statistical methodology known as Item Response Theory to convert raw student responses to final test scores. This "scaling" of responses gives a more regular distribution of scores, and allows some comparison across domains and cycles. Science test results were scaled so that the average score across OECD countries on the overall test is 500, and the standard deviation is 100. This means that 68% of students' scores fall between 400 and 600 (i.e. within one standard deviation above or below the average of 500). Subscales are similarly scaled, albeit with slightly different means (averages) and standard deviations.

Significant difference A significant difference in achievement between groups is one that a statistical test has established is unlikely to be due to chance. As well as the statistical difference between scores, attention should be given to the size of the difference.

Standard error (SE) This report presents mean, or average, test scores obtained by the total sample and by various groups of students (e.g., female students). These scores are *estimates*. Thus, we estimate that a country's reading literacy score is X, based on the sample we have selected. However, it is unlikely that the 'true' score for a country is exactly the one based on the performance of the sample, as some variation, or error, around scores is to be expected. Each mean has a standard error, which allows us to estimate how accurately the mean found in our sample reflects the 'true' mean in the population.

95% Confidence interval We use standard errors (see above) to calculate a *95% confidence interval* around an estimate (e.g., Ireland's mean science score). The interval is a range of scores in which there is a 95% chance that the 'true' score falls. For example, an estimated mean of 512 might have a 95% confidence interval of 508 – 516. There is a 5% chance the true score is outside this interval.

1 Overview of PISA

What is PISA?

The OECD Programme for International Student Assessment (PISA) is an international survey of 15-year-old students that takes place every three years. Students' *literacy* in science, mathematics and reading is assessed in PISA. Fifteen-year-olds are the target group because this age marks the end of compulsory schooling in many countries. The term literacy is used to emphasise the ability to apply knowledge, rather than simply to reproduce facts that have been studied in a curriculum. Thus, PISA aims to assess students' preparedness for the reading, mathematical and scientific demands of future education and adult life. In 2006, almost 400,000 students were assessed, spread across 57 countries (or regions), including Ireland (Figure 1.1).

PISA produces internationally comparable education 'indicators' (measures related to education systems) and is used by many countries to provide guidance on developing educational policy.

Figure 1.1 Countries participating in PISA 2006

Source: OECD, 2007.

Who Takes Part?

In Ireland, 165 randomly selected schools were invited to take part in PISA 2006. The selection process ensured an appropriate mixture of schools by type (secondary, community / comprehensive, vocational), size, and gender composition. Except for one school which had closed down, all initially selected schools agreed to participate. Participating schools can be considered as representative of schools nationally.

In each school, up to 35 15-year-old students were chosen randomly to take part. Just under 4% of students were excluded (due to additional educational needs that precluded participation) or were not eligible to participate. Ireland's weighted final response rate for eligible students was 83.8%. Reasons for non-participation included parental or student refusal (almost 4%), and absence on the test day (just under 13%). Of the 4,585 participants in Ireland, 59% were in Third Year, 21% in Transition Year, 17% in Fifth Year, almost 3% in Second Year, and just two in First Year. School and student response rates in Ireland exceeded the minimum rates set by the OECD (85% for school participation and 80% for student participation).

What Does PISA Measure?

PISA assesses student knowledge and skills in three "domains" (scientific literacy, reading literacy, and mathematical literacy[1]) every three years. Each year, one of these areas is assessed in depth, while the other two are assessed more broadly. In 2006, science was the focus of the assessment. Students in Ireland performed significantly above the OECD average on reading literacy and scientific literacy in PISA 2000 and 2003. On both occasions, for mathematical literacy, students achieved a mean score that was just above the OECD average, but not significantly so.

Students are assessed using a paper-and-pencil test containing a mixture of multiple-choice items and items where students need to write their own answers. Students and principals also complete questionnaires. Data from these questionnaires allow student and school characteristics to be linked to student achievement on the test. Tests and questionnaires were jointly developed by countries taking part in PISA. Although the international element of PISA did not include a science teacher questionnaire, such a questionnaire was developed and administered in Ireland as part of PISA 2006. Some of the main results of the science teacher survey are described in *Implementing the Revised Junior Certificate Science Syllabus: What Teachers Said* (Eivers, Shiel & Cheevers, 2006).

Assessment in each domain is guided by a framework which defines the areas to be assessed. These detailed definitions informed the development of test items, including the types of item used and the topics covered. The PISA 2006 framework (OECD, 2006) and sample test items can be downloaded from *www.pisa.oecd.org* (sample questionnaires can be obtained from *www.erc.ie/pisa*). In the following sections, we explain how the final set of items included in the assessment was derived from the definition of each domain.

Measuring Scientific Literacy

Scientific literacy is defined as an individual's

- scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues;
- understanding of the characteristic features of science as a form of human knowledge and enquiry;
- awareness of how science and technology shape our material, intellectual, and cultural environments;
- willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen. (OECD, 2006, p.23)

Four interrelated aspects of scientific literacy are of particular importance: context; competencies; *knowledge of* scientific topics and *knowledge about* scientific methods and processes; and attitudes (Figure 1.2).

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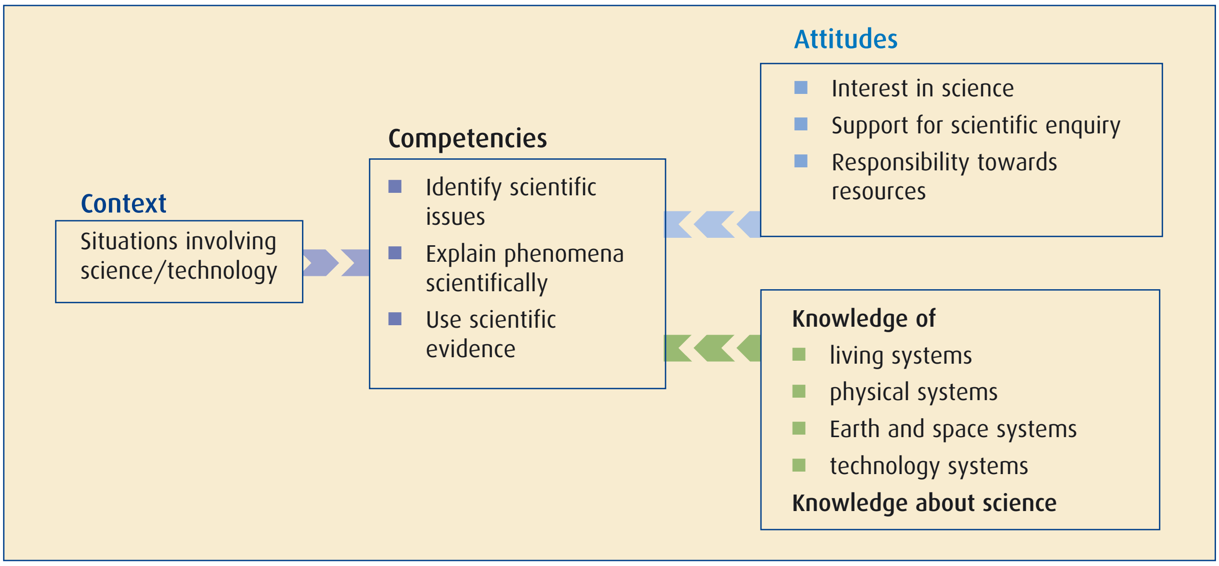
[1] Throughout this report, the terms science, reading, and mathematics are used interchangeably with scientific literacy, reading literacy, and mathematical literacy, respectively.

Figure 1.2: Diagram of the PISA 2006 framework for the assessment of scientific literacy



Adapted from OECD (2006), Figure 1.1

The development of PISA science test items was guided by the central elements of the framework (Appendix A contains items exemplifying different framework elements). The contexts for test questions represent a mixture of personal (self, family, peer group), social (community), and global (life across the world) situations. Over half the items (55.3%) were framed in a social context, while 27.2% had a global context, and 17.5% a personal context. The three main competencies underpinning scientific literacy also defined the final pool of science assessment items. Almost half (48%) of the 103 science items related to *explaining phenomena scientifically*, while 30% related to *using scientific evidence*, and 22% to *identifying scientific issues* (Table 1.1).

Table 1.1: Distribution of PISA 2006 science items, by competency

Competency	Key skills	% of items
Identify scientific Issues	Recognise issues that can be investigated scientifically, identify keywords to search for scientific information, and recognise the key features of a scientific investigation.	**22.3**
Explain phenomena scientifically	Apply knowledge of science in a given situation, describe / interpret phenomena scientifically and predict changes, and identify appropriate descriptions, explanations and predictions	**47.6**
Use scientific evidence	Interpret scientific evidence and make and communicate conclusions, identify the assumptions, evidence and reasoning behind conclusions, and reflect on the societal implications of science and technological developments.	**30.1**

Each PISA science item can be categorised as requiring students to demonstrate either *knowledge of science* (56% of items) or *knowledge about science* (44% of items). Items examining the former were divided across the main fields of science, with *living systems* accounting for 21% of all test items, *physical systems* 16%, *Earth and space systems* 11%, and *technology systems* 8% (Table 1.2). Within each of these fields, topics were selected by considering their relevance to real-life situations, whether they represented important scientific concepts, and their appropriateness to the developmental level of 15-year-olds.

Items assessing *knowledge about science* were divided into ones that examined *scientific enquiry* (how scientists acquire knowledge – how they get their data) and *scientific explanations* (the results of scientific enquiry – how the data are used). The former accounted for 23% of items and the latter for 20% of items.

Table 1.2: Distribution of PISA 2006 science items, by knowledge of and about science

		% of items
Knowledge *of* science	Earth and space systems	10.7
	Living systems	21.4
	Physical systems	16.5
	Technology systems	7.8
Knowledge *about* science	Scientific enquiry	23.3
	Scientific explanations	20.4

Percentages do not sum to 100 due to rounding.

Each item assessing scientific literacy required students to demonstrate one of the three scientific competencies and to use *knowledge of science* or *knowledge about science*. The PISA 2006 science assessment also evaluated students' attitudes in three areas: *interest in science*, *support for scientific enquiry* and *responsibility towards resources and environments*. Attitudes were assessed not only in a student questionnaire, but also in the test booklets, where students were asked a number of attitudinal questions in relation to some of the test items they had completed.

What Scales are Reported?

As well as an overall scale, the following achievement scales are reported for PISA science:

- Competency scales
  - *identifying scientific issues, explaining phenomena scientifically, using scientific evidence.*
- Knowledge scales
  - *knowledge of living systems, knowledge of physical systems, knowledge of Earth and space systems,* and *knowledge about science*[2]

Measuring Reading Literacy

Reading literacy is defined as "understanding, using and reflecting on written texts, in order to achieve one's goals, to develop one's knowledge and potential and to participate in society" (OECD, 2006, p. 46). The PISA conceptualisation of reading literacy categorises texts as continuous and non-continuous. The former is typically composed of sentences grouped into paragraphs, which may join to form part of a larger unit, such as a newspaper article, or a book chapter. Non-continuous texts differ from continuous texts in the way in which they are organised, and require different reading approaches. Examples include charts, diagrams, forms, and advertisements.

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[2] Although *knowledge of technology systems* is included in the PISA science framework and assessment, it is not analysed separately as it was assessed by too few items.

Approximately two-thirds of reading items in PISA 2006 were based on continuous texts, and just over one-third on non-continuous texts. PISA also categorised reading items by the processes underlying reading literacy and by situations. The processes included *retrieving information, interpreting a text*, and *reflection and evaluation*, while the situations in which items were located included *reading for private use, for public use, for education,* and *for work*. As reading was a minor domain, data are reported only for an overall reading literacy scale.

Measuring Mathematical Literacy

Mathematical literacy is defined as "an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgements and to engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen" (OECD, 2006, p. 72). The PISA conceptualisation of mathematical literacy is based on the Realistic Mathematics Education movement, which emphasises the notion of "mathematising". This process involves taking a problem in a real-world context, organising it according to mathematical concepts, and gradually "trimming away the reality". Once the key features of the problem are recognised, it can be solved. The final step in mathematising a problem is to make sense of the mathematical solution in terms of the real situation.

Test items were chosen to reflect the main elements of how mathematical literacy was defined – context, content, and competency. Items were divided across the four main contexts of *personal, educational / occupational, public,* and *scientific*. Four "overarching ideas" guided the selection of content: *space and shape; change and relationships; quantity;* and *uncertainty*. Items also examined one of three competencies: *reproduction, connections*, and *reflection*. Items assessing *reproduction* examined reproduction of practised knowledge, including performing routine procedures and computations, applying standard algorithms, and manipulating formulae. *Connections* items sought evidence that students could integrate or connect ideas or different representations of a problem. Finally, items assessing *reflection* examined students' ability to engage in advanced reasoning, argumentation, generalisation, and the use of multiple complex mathematical methods. As mathematics was a minor domain, performance is reported only for an overall mathematical literacy scale.

What do the Scores and Scales Mean?

PISA uses a technique called Item Response Theory (IRT) to develop scales of student performance. In 2006, the science data were scaled so that the average overall science test score for students in OECD countries[3] is 500 and the standard deviation is 100. This means that roughly 68% of students have scores between 400 and 600 (500 ± 100)[4]. The subscales follow a similar model to the overall scale, but with slight variation in the means and standard deviations. For example, the science competency subscale means range from 498.8 to 500.4.

The scales for reading and mathematics are slightly different. First, because they are minor domains, we report only on an overall scale. Second, the scales are "anchored" in the cycle in which they were the major domain (2000 for reading and 2003 for mathematics). For example, the OECD mean for reading was set at 500 on the basis of the 2000 results, which is why the means in 2003 and 2006 are not equal to 500. Anchoring the scale allows us to examine how overall performance varies from one cycle to the next.

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[3] Domains were scaled using achievement data from OECD countries only.

[4] While the OECD-wide standard deviation for the overall science scale was set at 100, the country average standard deviation is reported as 95. This is a simple average of the country-level standard deviations for individual OECD countries.

Because scales are anchored in the cycle in which they were the major domain, accurate trend data cannot be established until *after* a domain has been the major domain. This means that while we can examine trends in reading performance since 2000, we can only examine mathematics trends between 2003 and 2006. Since 2006 is the first time science was the major domain, we cannot provide accurate data on trends, though we can compare performance of countries relative to the OECD average in each cycle.

For all scales it is important to remember that PISA assesses samples of students, not every 15-year-old in the 57 participating countries. Consequently, the scores are *estimates* of the true means of the populations, and the accuracy of the estimate is influenced by the precision of the sample. For these reasons, we consider standard errors and confidence intervals (see *Statistical Terms Used*) when interpreting a score. Put simply, a score in itself should not be taken as an absolute value, but viewed as one score in a range in which the "true" score falls.

PISA also uses an item difficulty scale, whereby each test item is given a score to indicate how easy or difficult it was for students to answer correctly. The item difficulty scale has the same mean as the student achievement scale. Thus, an item with a difficulty score of, say, 621 is a difficult item that most students did not answer correctly, an item with a score of 500 is of average difficulty, and an item with a difficulty score of 350 would be considered an easy item.

Another important way in which PISA describes results is through the use of proficiency levels, which are specific to each domain. Proficiency scales group students into levels, based on the (science, reading or mathematics) skills a student in a given group is able to demonstrate. For science and mathematics, level 6 is the highest proficiency level, while for reading it is level 5. Students at the highest proficiency level demonstrate comprehensive understanding and skills related to the domain. In contrast, on each domain, the skills of those categorised as level 1 are very limited. A small group of students are classified as below level 1 because they have difficulty showing competency in the particular domain, even in response to the most basic (level 1) PISA items. According to the OECD (2007), students at or below level 1 are likely to have great difficulty with science (or reading or mathematics) in their future education and in real-life situations.

2 Overall Performance by Country

This chapter describes overall performance on the three PISA domains of scientific literacy, reading literacy, and mathematical literacy. Ireland's average score on each of the domains is compared with the OECD average and with the average scores of a selection of other countries. More detailed analyses of Ireland's performance on these domains are presented in Chapters 3 (science) and 5 (reading and mathematics).

How to Read Table 2.1

Table 2.1 shows the mean score and standard error (see *Statistical Terms Used*) for participating countries on each domain. Countries are sorted in descending order within each domain by their mean scores. A "traffic light" system of colour codes shows how each country performed relative to the OECD mean.

Green zone = significantly higher than the OECD average (using a 5% significance level)
Amber zone = not significantly different from the OECD average
Red zone = significantly lower than the OECD average.

The **IRL** columns compare each country's performance to Ireland's. For a given country, the symbol ▲ denotes a significantly higher mean score, **0** denotes a mean score that does not differ significantly from Ireland's, and ▼ denotes a significantly lower mean score.

When examining whether two mean scores differ significantly, always consider the associated standard errors. The larger they are, the larger the gap required for a difference to be significant. For example, Slovenia's small standard error for reading helps to explain why it is in green while Japan, with a higher mean reading score and much larger standard error, is shown in amber. The table assumes that single comparisons are being made. As, in fact, many comparisons are made, the likelihood of finding a significant difference by chance is well above the conventional 5% level. Therefore, countries on the borders of colour zones and with relatively large standard errors cannot confidently be distinguished from the OECD mean. A similar caveat applies when comparing countries with Ireland.

Overall Science Performance

Ireland's average score of 508.3 on the combined science scale is significantly higher than the OECD average of 500, meaning that Ireland is colour-coded green in Table 2.1. Some countries, such as Sweden and France, are shown in amber, meaning that they do not differ significantly from the OECD average, while countries such as Greece, Spain and the US are in red, indicating levels of scientific literacy below the OECD average. Ireland's mean score is the 20th highest of the 57 participating countries, and the 14th highest of the 30 OECD countries. Applying a 95% confidence interval (see *Statistical Terms Used*), Ireland's true rank is between 10th and 16th among OECD countries.

We can also group countries into those that have a significantly higher score than Ireland, those that do not differ significantly from Ireland, and those that have a significantly lower score. Twelve countries (shown by the symbol ▲ in the **IRL** column and including Finland, Hong Kong-China, Canada, and Estonia) have a significantly higher mean score. Nine countries (indicated by **0** and including the UK, Germany and the Czech Republic) have mean scores that do not differ significantly from that of Ireland, and 35 (indicated by ▼ and including Denmark, France and the US) have a mean score that is significantly lower.

Table 2.1: Mean country scores and standard errors for each domain in PISA 2006, and position relative to the OECD and Irish means

Science			
	Mean	SE	IRL
Finland	563.3	2.02	▲
Hong Kong-Ch.	542.2	2.47	▲
Canada	534.5	2.03	▲
Chinese Taipei	532.5	3.57	▲
Estonia	531.4	2.52	▲
Japan	531.4	3.37	▲
New Zealand	530.4	2.69	▲
Australia	526.9	2.26	▲
Netherlands	524.9	2.74	▲
Liechtenstein	522.2	4.10	▲
Korea	522.1	3.36	▲
Slovenia	518.8	1.11	▲
Germany	515.6	3.80	0
United Kingdom	514.8	2.29	0
Czech Republic	512.9	3.48	0
Switzerland	511.5	3.16	0
Macao-China	510.8	1.06	0
Austria	510.8	3.92	0
Belgium	510.4	2.48	0
Ireland	**508.3**	**3.19**	
Hungary	503.9	2.68	0
Sweden	503.3	2.37	0
OECD MEAN	**500.0**	**0.53**	▼
Poland	497.8	2.34	▼
Denmark	495.9	3.11	▼
France	495.2	3.36	▼
Croatia	493.2	2.45	▼
Iceland	490.8	1.64	▼
Latvia	489.5	2.97	▼
United States	488.9	4.22	▼
Slovak Republic	488.4	2.59	▼
Spain	488.4	2.57	▼
Lithuania	488.0	2.76	▼
Norway	486.5	3.11	▼
Luxembourg	486.3	1.05	▼
Russian Fed.	479.5	3.67	▼
Italy	475.4	2.02	▼
Portugal	474.3	3.02	▼
Greece	473.4	3.23	▼
Israel	453.9	3.71	▼
Chile	438.2	4.32	▼
Serbia	435.6	3.04	▼
Bulgaria	434.1	6.11	▼
Uruguay	428.1	2.75	▼
Turkey	423.8	3.84	▼
Jordan	422.0	2.84	▼
Thailand	421.0	2.14	▼
Romania	418.4	4.20	▼
Montenegro	411.8	1.06	▼
Mexico	409.7	2.71	▼
Indonesia	393.5	5.73	▼
Argentina	391.2	6.08	▼
Brazil	390.3	2.79	▼
Colombia	388.0	3.37	▼
Tunisia	385.5	2.96	▼
Azerbaijan	382.3	2.75	▼
Qatar	349.3	0.86	▼
Kyrgyzstan	322.0	2.93	▼

Reading			
	Mean	SE	IRL
Korea	556.0	3.81	▲
Finland	546.9	2.15	▲
Hong Kong- Ch.	536.1	2.42	▲
Canada	527.0	2.44	▲
New Zealand	521.0	2.99	0
Ireland	**517.3**	**3.54**	
Australia	512.9	2.06	0
Liechtenstein	510.4	3.91	0
Poland	507.6	2.79	▼
Sweden	507.3	3.44	▼
Netherlands	506.7	2.92	▼
Belgium	500.9	3.04	▼
Estonia	500.7	2.93	▼
Switzerland	499.3	3.06	▼
Japan	498.0	3.65	▼
Chinese Taipei	496.2	3.38	▼
United Kingdom	495.1	2.26	▼
Germany	494.9	4.41	▼
Denmark	494.5	3.18	▼
Slovenia	494.4	0.99	▼
Macao-China	492.3	1.10	▼
OECD MEAN	**491.8**	**0.60**	▼
Austria	490.2	4.08	▼
France	487.7	4.06	▼
Iceland	484.4	1.95	▼
Norway	484.3	3.18	▼
Czech Rep.	482.7	4.18	▼
Hungary	482.4	3.28	▼
Latvia	479.5	3.73	▼
Luxembourg	479.4	1.28	▼
Croatia	477.4	2.81	▼
Portugal	472.3	3.56	▼
Lithuania	470.1	2.98	▼
Italy	468.5	2.43	▼
Slovak Rep.	466.3	3.06	▼
Spain	460.8	2.23	▼
Greece	459.7	4.04	▼
Turkey	447.1	4.21	▼
Chile	442.1	4.99	▼
Russian Fed.	439.9	4.32	▼
Israel	438.7	4.58	▼
Thailand	416.8	2.59	▼
Uruguay	412.5	3.43	▼
Mexico	410.5	3.06	▼
Bulgaria	401.9	6.91	▼
Serbia	401.0	3.46	▼
Jordan	400.6	3.27	▼
Romania	395.9	4.69	▼
Indonesia	392.9	5.92	▼
Brazil	392.9	3.74	▼
Montenegro	392.0	1.22	▼
Colombia	385.3	5.08	▼
Tunisia	380.3	4.02	▼
Argentina	373.7	7.17	▼
Azerbaijan	352.9	3.12	▼
Qatar	312.2	1.20	▼
Kyrgyzstan	284.7	3.48	▼

Mathematics			
	Mean	SE	IRL
Chinese Taipei	549.4	4.10	▲
Finland	548.4	2.30	▲
Hong Kong-Ch.	547.5	2.67	▲
Korea	547.5	3.76	▲
Netherlands	530.7	2.59	▲
Switzerland	529.7	3.15	▲
Canada	527.0	1.97	▲
Macao-China	525.0	1.30	▲
Liechtenstein	525.0	4.21	▲
Japan	523.1	3.34	▲
New Zealand	522.0	2.39	▲
Belgium	520.3	2.95	▲
Australia	519.9	2.24	▲
Estonia	514.6	2.75	▲
Denmark	513.0	2.62	▲
Czech Republic	509.9	3.55	0
Iceland	505.5	1.81	0
Austria	505.5	3.74	0
Slovenia	504.5	1.04	0
Germany	503.8	3.87	0
Sweden	502.4	2.41	0
Ireland	**501.5**	**2.79**	
OECD MEAN	**497.7**	**0.54**	0
France	495.5	3.17	0
United Kingdom	495.4	2.14	0
Poland	495.4	2.44	0
Slovak Republic	492.1	2.82	▼
Hungary	490.9	2.89	▼
Luxembourg	490.0	1.07	▼
Norway	489.8	2.64	▼
Lithuania	486.4	2.93	▼
Latvia	486.2	3.03	▼
Spain	480.0	2.33	▼
Azerbaijan	476.0	2.26	▼
Russian Fed.	475.7	3.87	▼
United States	474.4	4.02	▼
Croatia	467.2	2.37	▼
Portugal	466.2	3.07	▼
Italy	461.7	2.28	▼
Greece	459.2	2.97	▼
Israel	441.9	4.35	▼
Serbia	435.4	3.51	▼
Uruguay	426.8	2.61	▼
Turkey	423.9	4.90	▼
Thailand	417.1	2.34	▼
Romania	414.8	4.21	▼
Bulgaria	413.4	6.13	▼
Chile	411.4	4.58	▼
Mexico	405.7	2.93	▼
Montenegro	399.3	1.37	▼
Indonesia	391.0	5.63	▼
Jordan	384.0	3.30	▼
Argentina	381.3	6.24	▼
Colombia	370.0	3.78	▼
Brazil	369.5	2.93	▼
Tunisia	365.5	3.96	▼
Qatar	318.0	1.02	▼
Kyrgyzstan	310.6	3.41	▼

🟩	Significantly above OECD average	▲	Signicantly higher than Ireland
🟧	At/near OECD average	0	Not significantly different to Ireland
🟥	Significantly below OECD average	▼	Significantly lower than Ireland

Overall Reading Performance

Ireland's mean score on the reading scale is 517.3, which is significantly higher than the OECD mean of 491.8. In terms of country rankings, Ireland is the 6th highest of the 56 participating countries[5], and the 5th highest of the 29 OECD countries. Applying a 95% confidence interval to our ranking, we can say that Ireland's true rank is between the 4th and 6th highest amongst OECD countries.

Ireland's mean score is significantly lower than those of four countries (Korea, Finland, Hong Kong-China, and Canada), and not significantly different from the mean score in three (New Zealand, Australia, and Liechtenstein). All remaining 48 countries performed significantly poorer than Ireland. Some, such as the UK, France, and Germany are shown in amber, denoting performance not significantly different from the OECD average, while others, such as Norway, the Czech Republic, and Spain are shown in red, denoting performance below the OECD average.

Overall Mathematics Performance

Ireland's mean score on the mathematics scale is 501.5, which places the country in amber as the mean does not differ significantly from the OECD mean of 497.7. In terms of country rankings, Ireland's mean score is the 22nd highest of the 57 participating countries, and the 16th highest of the 30 OECD countries. Applying a 95% confidence interval, we can say that Ireland's true rank is likely to be between the 12th and 17th highest amongst OECD countries.

Ireland's mean score is significantly lower than those of 15 countries (with Chinese Taipei, Finland, Hong Kong-China, and Korea all obtaining means at least 46 points higher than Ireland's), and not significantly different from the mean score in nine countries (including Germany, France and the UK). All remaining 32 countries (including OECD member states the Slovak Republic, the US, and Italy) performed significantly less well than Ireland.

Performance Across Domains

Countries tend to perform at the same level on each of the three domains. Of the 20 countries that scored above the OECD average on science, 13 are also coded as green for reading and 17 for mathematics (Table 2.1). In other words, if a country is above average on one domain, it is very likely to be above average on other domains.

Note that Finland's students obtain very high mean scores on each domain. They obtain by far the highest mean score for science and the second highest for reading and mathematics. Hong Kong-China also performs very well in each domain, featuring among the top three countries on each of the three domains.

Ireland's students show considerably more variation across domains. They perform well above average on reading, but are only average on mathematics. While Ireland is located within the green zone for science, it is at the colour border with amber, indicating a lack of certainty about the above average nature of the performance.

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[5] The US is excluded from the data relating to reading literacy as an error in the printed test booklets affected performance on the reading domain.

Diversity Within Countries

Countries that are similar in terms of average scores can vary very much in other ways. To illustrate this we have used the difference between scores at the 5th and 95th percentiles as an indicator of the spread of achievement in a country. The 5th percentile can be taken as indicating low-achieving students and the 95th as indicating high-achieving students.

Ireland and Finland have the narrowest spread amongst OECD countries (268 and 266 score points, respectively) for mathematics. This means that, despite very different national average scores, Ireland and Finland are alike in having a smaller than average gap between very high and very low achievers. In contrast, despite a national average score that is very similar to Ireland's, Germany's gap is almost 325 points.

Ireland's difference between these key percentiles for reading (303 points) is also much smaller than the OECD average of 324. As with science, Finland had the smallest difference (265 points) between the two percentile markers. For science, the achievement gap of 309 points between Irish students at the 5th and 95th percentile is very close to the OECD average of 311 points. While Ireland's average science score falls within a few points of that obtained by UK students, there is a much larger gap (348 points) between the percentile markers for the UK. At the 5th percentile, UK students tended to perform less well than Irish students (i.e., the UK's low achievers were outperformed on science by Ireland's low achievers), while at the 95th percentile they tended to perform much better (i.e., the UK's high achievers outperformed Ireland's high achievers on science).

Trends in Overall Performance

This section summarises trends over time in overall OECD performance; trends in Ireland's performance are discussed in Chapters 3 and 5. As this is only the third cycle of PISA, comparison points are limited (indeed, non-existent for science, as 2006 is the first time science was the major domain). Some countries in the 2006 dataset were not included in one or both of the previous cycles, either because they did not participate (e.g., Turkey in 2000) or because they did not meet certain response rate requirements (e.g., the UK in 2003).

Overall performance on reading has remained reasonably stable since 2000. Comparing countries that took part in both cycles, the 2006 OECD mean of 491.8 points is not significantly lower than the mean of 498.0 found in 2000, nor does it differ significantly from the 2003 mean.

In PISA 2006, the OECD average mathematics score was 497.7, which is 2 points lower than the mean of 500 set in 2003 (a non-significant difference).

3 Scientific Literacy

As noted in Chapter 2, the score of Ireland's students on the overall science scale (508.3) is significantly higher than the OECD average (500). In this chapter, we examine the performance of Irish students in more detail on overall scientific literacy, and on the science subscales. We describe "proficiency levels" for science, comparing Ireland's performance with OECD averages. Gender differences are described, and Irish performance in 2006 is compared with performance in previous cycles.

Performance on Science Subscales

As well as an overall scientific literacy score, PISA provides scores on three science competencies (*identifying scientific issues, explaining phenomena scientifically, using scientific evidence*) and on *knowledge of* and *about science*. Table 3.1 shows the mean scores for Ireland and the mean OECD scores for each subscale. The OECD country average varies slightly across subscales, but always remains close to 500. In contrast, there is considerable variation in the average performance of Irish students across the subscales.

Table 3.1: Mean scores and standard errors on science subscales in PISA 2006 (Ireland and OECD averages)

Scale type		Ireland		OECD		Diff (IRL–OECD)
		Mean	SE	Mean	SE	
Competency	Identify scientific issues	515.9	3.28	498.8	0.55	**+17.1**
	Explain phenomena scientifically	505.5	3.22	500.4	0.54	+5.1
	Use scientific evidence	505.9	3.45	499.2	0.62	**+6.7**
Knowledge ...	about science	512.7	2.69	499.9	0.46	**+12.9**
	of Earth & space systems	508.1	2.82	499.5	0.49	**+8.6**
	of living systems	505.6	2.95	501.8	0.47	+3.7
	of physical systems	504.5	2.64	500.0	0.46	+4.4

Significant differences are in bold in the Diff column.

Students in Ireland performed best on *identifying scientific issues*, achieving a mean score of 515.9. This is well above the OECD mean and the 8th highest score among OECD countries. The Irish mean for *using scientific evidence* (505.9) is also significantly above the OECD mean. While the mean for *explaining phenomena scientifically* (505.5) is above the OECD mean, it is not significantly so. On each of the three competency scales, Finnish students obtained the highest mean score, which was at least 56 points above the OECD average score.

Ireland's mean scores on *knowledge about science* (512.7) and *knowledge of Earth and space systems* (508.1) are significantly above the corresponding OECD average scores. However, while mean scores for *knowledge of living systems* (505.6) and *physical systems* (504.5) are above the OECD average, they are not significantly so. As with the competency subscales, Finland achieved the highest score on each the of subscales relating to *knowledge about* and *knowledge of science*. The highest mean score obtained by Finnish students (573.8) was on *knowledge of living systems* – over 70 points higher than the OECD average and almost 70 points higher than the mean score of Irish students on the subscale. To put this in context, the OECD (2007) estimated that a 34-point difference is roughly equivalent to the effects of one year of schooling.

Cluster analyses were conducted to identify groups of countries with similar strengths and weaknesses on subscales (OECD, 2007). Ireland is one of a group of nine countries in which students showed a (relative) strength in *identifying scientific issues*. Interestingly, with the exception of the Netherlands and Ireland, all other countries in the group performed below the OECD average on the overall science scale.

In Ireland, there is a small gap between student performance with regard to *knowledge about science* and *knowledge of science*[6]. The OECD average gap is also small. However, if individual countries are examined, large differences are found in a number of countries. For example, in France there is a 29-point gap favour of *knowledge about science*, while in the Czech Republic the gap is 29 points in favour of *knowledge of science*. Furthermore, Ireland's mean scores for the *knowledge of science* domains (*physical systems, living systems*, and *Earth and space systems*) are quite similar. However, in most countries there are noticeable differences in student performance between these domains. For example, although Korean students performed well overall, their mean score for *knowledge of living systems* is below the OECD average, and over 30 points lower than their mean scores on *physical systems* and *Earth and space systems*.

Science Proficiency Levels

Proficiency levels involve grouping students' scores on a continuous scale into levels, based on the skills a student in a given group is likely to be able to demonstrate. There are six such levels for science – level 6 is the most advanced, and level 1 the least advanced. There is also a "below level 1" category for students who did not demonstrate competencies required by the easiest PISA tasks. Each level is defined by the ability to complete more difficult tasks than those exemplifying the level(s) below it, while also including the skills required at the lower levels. Table 3.2 describes the skills that exemplify each proficiency level on the overall science scale, shows the range of scale scores that each level represents, and lists a test item that at least half of students at that level would be expected to answer correctly. The items referred to, and some information about them, can be found in Appendix A.

At just over 1%, the percentage of Irish students at proficiency level 6 is very similar to the OECD average, as is the percentage at either levels 5 or 6 (9% for both Ireland and the OECD). This figure may be compared with the 21% of students in Finland who scored at level 5 or 6. In 15 countries (including Turkey, Argentina and Mexico) less than one percent attained levels 5 or 6.

Two items from the Greenhouse unit represent examples of the types of item that students must be able to answer to attain levels 4, 5 and 6. Question 5 (level 6) requires students to *explain phenomena scientifically,* by analyzing a conclusion and considering other factors that could influence the greenhouse effect. The question has an item difficulty score of 709 and was answered correctly by only 19% of students (across the OECD and in Ireland).

Question 4 asks students to *use scientific evidence*, by identifying a portion of a graph that does not provide evidence supporting a conclusion. A full credit (FC) answer is an example of the skills typifying level 5, while a partial credit (PC) response is an example of the scientific skills of students at level 4. In Ireland, 23% of students recorded a fully correct response (the OECD average was 22%) and 28% a partially correct response (OECD average 24%).

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[6] The *knowledge of science* score reported by the OECD is simply an average of the three *knowledge of science scales*. It should only be regarded as a rough summary estimate, as it has not been properly scaled.

Table 3.2: Proficiency levels on the PISA 2006 combined science scale, illustrative examples of test items at each level, and percentages of students achieving each level (Ireland and OECD average)

Level Cut-point Item	At this level, a majority of students can ...	IRL		OECD	
		%	SE	%	SE
Level 6 Above 707.9 Greenhouse Q5	consistently identify, explain & apply scientific knowledge, and knowledge *about* science in a variety of complex life situations. use evidence from different sources to justify decisions. use advanced scientific reasoning to develop arguments and solve problems, including in unfamiliar scientific situations.	1.1	0.19	1.3	0.04
Level 5 633.3–707.9 Greenhouse Q4 (FC)	Identify scientific components, explain and apply scientific concepts and knowledge about science in many complex life situations link knowledge appropriately & bring critical insights to life situations. construct evidence-based explanations & arguments.	8.3	0.62	7.7	0.10
Level 4 558.7–633.3 Greenhouse Q4 (PC)	use non-complex situations or issues to make inferences about the role of science or technology. integrate information from different science disciplines. reflect on their actions & communicate decisions using scientific knowledge & evidence.	21.4	0.87	20.3	0.16
Level 3 484.1–558.7 Greenhouse Q3	identify clearly described scientific issues in a range of contexts. interpret & use scientific concepts from different disciplines & apply them directly. develop short communications using facts & make decisions based on scientific knowledge.	29.7	0.98	27.4	0.17
Level 2 409.5–484.1 Grand Canyon Q3 &5	provide possible explanations in familiar contexts or draw conclusions based on simple investigations. engage in direct reasoning & make literal interpretations of the results of scientific inquiry.	24.0	0.91	24.0	0.17
Level 1 334.9–409.5	only apply a limited store of scientific knowledge to a few, familiar situations. present scientific explanations that are obvious & follow concretely from given evidence.	12.0	0.82	14.1	0.15
Below Level 1 Less than 334.9	not respond correctly to more than 50% of Level 1 questions. Scientific literacy is not assessed by PISA.	3.5	0.47	5.2	0.11

Two items from the Grand Canyon unit show the type of questions that students at the lower proficiency levels are typically able to answer. Both items require students to *explain phenomena scientifically*. To answer question 5 students have to identify receding seas as the most likely of four options to be the source of fossils at the Grand Canyon. It is a relatively easy item, correctly answered by 70% of students in Ireland and 76% across the OECD. It is an example of an item which had a difficulty level located on the boundary between levels 1 and 2.

Level 2 is used by the OECD as the "baseline" proficiency level for science (students below this level are considered to have insufficient scientific literacy to allow them to participate actively in situations related to science and technology).

Overall, Ireland tends to have fewer students categorised below level 2 (16% versus an OECD average of 19%). This compares favourably with countries such as the US and Italy, where approximately one quarter of students do not reach baseline proficiency. However, it falls far short of Finland, where only 4% of students do not achieve basic proficiency in science.

Proficiency levels were also reported for each science competency (Table 3.3). For *identifying scientific issues*, the percentage of high-achieving students – those at proficiency levels 5 or 6 – is slightly higher in Ireland (11%) than the average across OECD countries (8%). However, for both *using scientific evidence* and *explaining phenomena scientifically*, the percentage at levels 5 or 6 in Ireland is similar to the OECD average. For each competency, Ireland has proportionally fewer students than the OECD average who fail to reach the baseline proficiency level of 2. In particular, Ireland had fewer than average low-achieving students on *identifying scientific issues* (5% fewer than the OECD average), with differences less pronounced for *using scientific evidence* (4% fewer) and *explaining phenomena scientifically* (3% fewer).

Table 3.3: Percentage of students at each proficiency level on the science competencies in PISA 2006 (Ireland and OECD)

	Identify scientific issues				Explain phenomena scientifically				Use scientific evidence			
	Ireland		OECD		Ireland		OECD		Ireland		OECD	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Level 6	1.8	0.33	1.3	0.04	1.8	0.32	1.8	0.05	1.6	0.25	2.4	0.06
Level 5	9.2	0.66	7.1	0.11	8.5	0.70	8.0	0.11	8.8	0.73	9.4	0.12
Level 4	22.9	0.87	20.0	0.16	19.9	0.90	19.7	0.15	21.5	1.12	19.8	0.16
Level 3	29.2	0.84	28.3	0.18	28.0	1.16	27.0	0.17	27.6	1.02	24.7	0.17
Level 2	23.2	1.08	24.6	0.17	24.6	1.04	24.0	0.17	22.6	0.84	21.7	0.16
Level 1	10.7	0.79	13.5	0.14	12.6	0.74	14.2	0.15	12.5	0.72	14.1	0.15
< Level 1	3.0	0.45	5.2	0.11	4.5	0.51	5.4	0.11	5.4	0.58	7.9	0.14

Taken as a whole, the proficiency scales suggest that Ireland's generally good performance on science is mainly due to the fact that proportionally fewer students score at the lower levels of proficiency rather than an unusually large proportion of high-achieving students.

Gender Differences in Scientific Literacy

Table 3.4 shows the gender differences amongst Ireland's students on the overall science scale and each of the subscales, as well as the average gender difference across all OECD countries. In Ireland, the overall science score of 508.5 obtained by females is almost identical to the 508.1 obtained by males. Across all OECD countries, males outperform females by 2.2 points (a significant difference). Amongst OECD countries, significant differences favouring males were found in six countries (the largest gap being a 10-point advantage for males in the UK) while significant differences (of roughly 12 points) favouring females were found only in Greece and Turkey.

Although there is no overall significant gender difference, some of the subscales show quite large gender differences for Ireland. Females outperform males by an average of just over 16 points on *identifying scientific issues*, and by nine points on *knowledge about science* (both differences are significant). Similar gender differences are found in the OCED average scores.

In Ireland and for the average across OECD countries, females obtained higher scores than males on *using scientific evidence*. While the difference is significant for the OECD, it is not for Ireland. Irish females obtained a higher mean score than males on *knowledge of living systems*, but the difference is not significant. This contrasts with the OECD average, where females obtained a significantly lower mean score than males.

In Ireland, males significantly outperformed females on *explaining phenomena scientifically*, *knowledge of physical systems* and *Earth and space systems* (by 9 points, 23 points, and 14 points, respectively). Averages for OECD countries on both subscales showed similar gender differences. With the exception of Turkey, males significantly outperformed females on *knowledge of physical systems* in all OECD countries, by an average of almost 26 points. Thus, Ireland's overall pattern of gender differences across science subscales was largely similar to the pattern for the OECD average differences.

Table 3.4: Gender differences on science subscales

Scale type		IRL Males		IRL Females		IRL	OECD
		Mean	SE	Mean	SE	M - F diff	M - F diff
Overall	Overall science scale	508.1	4.3	508.5	3.3	-0.4	**+2.2**
Competency	Identify scientific issues	507.7	4.4	523.9	3.5	**-16.2**	**-17.3**
	Explain phen. scientifically	510.2	4.4	500.9	3.5	**+9.3**	**+14.9**
	Use scientific evidence	502.5	4.8	509.3	3.5	-6.8	**-2.7**
Knowledge...	about science	508.2	3.7	517.2	2.8	**-9.0**	**-9.5**
	of Earth & space systems	515.2	3.9	501.2	3.2	**+14.0**	**+16.7**
	of living systems	504.6	4.0	506.5	3.4	-1.8	**+3.8**
	of physical systems	516.0	3.7	493.2	3.0	**+22.8**	**+25.7**

Significant differences are in bold in the Diff columns.

Irish Science Scores Over Time

PISA 2006 is the first time that science was the major domain, and the scale established will act as the basis for future trends. Thus, unlike reading and mathematics, it is not possible to analyse statistically trends in science achievement. We can, however, draw basic comparisons between Ireland's performance on science in 2006 with that reported in 2000 and 2003. Ireland's mean score for science in PISA 2000 was 513.4, compared to 505.4 in 2003 and 508.3 in 2006 (Table 3.5). In all three years, the mean science score for students in Ireland was significantly above the OECD average – albeit barely so in 2003.

We can also examine how Ireland fared in a "league table" of countries, although this can be difficult to interpret due to differences in the number of countries participating in each cycle. Furthermore, simple ranking may mean negligible differences in country scores are mistakenly considered to be substantive differences. For example, if the average scores of the 8th, 9th and 10th ranked countries differ by only a few points, this does not mean that the country in 8th position is substantively different to the country in 10th place. Given such small differences, it is quite conceivable that the relative positions could be swapped were the test re-administered.

Thus, we use 95% confidence intervals – meaning that there is a 95% chance that a country's "true" ranking is between the two bands of the interval. In the present cycle, Ireland's performance on science places us between 10th and 16th of 30 OECD countries, compared to between 9th and 16th of 29 OECD countries in 2003 and between 9th and 12th of 27 OECD countries in 2000. Thus, there has been reasonable stability in Ireland's science ranking over the years.

Table 3.5: A comparison of Irish and OECD mean scores on scientific literacy, 2000 to 2006

	Ireland		OECD average		Diff	Range of rank
	Mean	SE	Mean	SE	IRL - OECD	
2000	513.4	3.18	500.0	0.65	**+13.4**	9th - 12th of 27
2003	505.4	2.69	499.6	0.60	**+5.8**	9th - 16th of 29
2006	508.3	3.19	500.0	0.53	**+8.3**	10th - 16th of 30

Significant differences are in bold in the Diff column.

4 Science in PISA and the Junior Certificate

This chapter links performance on PISA science and the Junior Certificate Science Examination. The content of PISA science is compared with the content of the revised Junior Certificate science syllabus (rJCSS) – the syllabus experienced by most Junior Certificate 2006 students – and expected student familiarity with PISA items is linked to performance.

Linking PISA and Junior Certificate Examination Performance

Junior Certificate Examination data were obtained for 93.8% of students selected to participate in PISA in Ireland (i.e., including those originally sampled who had not completed the assessment). The remaining 6.2% had either not sat the examination or could not be found in the examination databases. Examination results in science, English, and mathematics were placed on separate Junior Certificate Performance Scales (JCPS), which take into account student grades across Higher, Ordinary and (where relevant) Foundation examination levels (Shiel et al, 2001).

There is a reasonably strong correlation (r= .71) between Junior Certificate science grade[7] and performance on PISA science: students who performed well on one were also likely to perform well on the other. The correlations between science grade and the three PISA science competency subscales are similar (ranging from .68 for *identifying scientific issues* to .69 for *explaining phenomena scientifically*). The correlation between PISA mathematics and Junior Certificate mathematics (.69) is also similar; the correlation for reading and Junior Certificate English (.64) is somewhat lower. Inter-correlations between the three PISA domains range from .82 for reading and mathematics performance to .88 for science and mathematics. Thus, the link between performance on the PISA domains is stronger than the link between any domain and its equivalent Junior Certificate subject.

Content of PISA and the rJCSS

A science expert group familiar with both the rJCSS and PISA compared both in terms of concepts (e.g., filtration or lung function) and competencies (e.g., *identifying scientific issues*) covered. Thirty-seven percent of PISA science items were described as based on competencies that were very familiar to Irish students, 63% were described as somewhat familiar, and none was rated unfamiliar (Table 4.1). Half of items were described as based on concepts that were very familiar to Irish students, 47% were described as somewhat familiar, and only 4% were perceived to be based on concepts unfamiliar to Irish students. Ratings did not vary by syllabus level.

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[7] As we have analysed only the rJCSS, the correlations reported for science are restricted to the 2006 Junior Certificate cohort. However, correlations for the 2005 cohort are very similar.

The last time PISA science items were rated for familiarity levels for Irish students was for PISA 2000 (Shiel et al, 2001). Then, between 49% and 54% (depending on syllabus level) of items were described as based on concepts unfamiliar to Irish 15-year-olds. Thus, there has been a marked change in the extent to which students in Ireland might be expected to be familiar with the concepts underlying PISA science items. However, it should be noted that this change applies only to students of the rJCSS[8].

Table 4.1: PISA 2006 science items rated on concept and competency familiarity

	Not familiar		Somewhat familiar		Very familiar	
	N	%	N	%	N	%
Competency	0.0	0.0	65	63.1	38	36.9
Concept	4	3.9	48	46.6	51	49.5

Examinations and marking schemes do not represent the totality of a syllabus, particularly when based on only one year. However, they can be taken as an indicator of the importance placed on various elements of a syllabus. For this reason, we examined how Higher and Ordinary level students were assessed for the 2006 rJCSS. The marks for both the written examination papers and the more practically-oriented Coursework A and B were examined to determine the proportions allocated to various elements of the PISA framework for science. Doing this revealed a concentration on one science competency to the relative neglect of the other two. At both Higher and Ordinary level, roughly two-thirds of marks were allocated to *explaining phenomena scientifically* while remaining marks were relatively evenly divided between *using scientific evidence* and *identifying scientific issues* (Table 4.2). Students in Ireland performed particularly well in PISA on *identifying scientific issues*, despite the apparently limited emphasis it received in the assessment of Junior Certificate science in 2006.

Table 4.2: The percentage of marks for the 2006 rJCSS relating to each of the PISA competency categories

	Explaining scientific phenomena	Identifying scientific issues	Using scientific evidence
Higher	62.3	17.8	19.8
Ordinary	66.8	16.8	16.3

Knowledge of physical systems was disproportionately represented at both Higher and Ordinary levels (receiving almost half of all marks), while roughly 22% of marks were allocated to *living systems* and close to 30% to *scientific enquiry* (Table 4.3). Neither *scientific explanations* nor *Earth and space systems* featured in the assessment at Ordinary or Higher level in 2006, while *technology systems* accounted for 1% of marks at Higher level.

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[8] While between 80% and 85% of those in Junior Cycle (depending on grade) had experienced the rJCSS, none of the Senior Cycle students had. Thus, roughly half of all PISA students had taken the rJCSS, approximately one-third had studied the older syllabus, and the remainder had not studied any science syllabus at Junior Cycle.

Table 4.3: The percentage of 2006 rJCSS marks allocated to elements of the PISA framework

	Knowledge about		Knowledge of			
	Scientific enquiry	Scientific explanations	Earth & space systems	Living systems	Physical systems	Tech. systems
Higher	29.7	0.0	0.0	21.8	47.5	1.0
Ordinary	31.2	0.0	0.0	21.7	47.2	0.0

The expert group attempted to position each PISA item within the rJCSS. Only 15% of items fell under rJCSS chemistry, while 30% fell under biology (Table 4.4). A further 22% of PISA items were classified under physics, and 18% under the general scientific skills set. Of the 15% of items adjudged to deal with topics not covered in the rJCSS, most related to the PISA science categories of *Earth and space systems,* or *scientific enquiry* and *scientific explanations.* However, it should be noted that some elements of *Earth and space systems* are covered in the Junior Certificate geography syllabus.

Table 4.4: PISA 2006 science items categorised by location within the rJCSS

Location in syllabus	N items	% items
Not on rJCSS	16	15.5
Biology	30	29.1
Chemistry	15	14.6
Physics	23	22.3
General scientific skills	19	18.4
Total	103	100.0

Effects of Familiarity on Test Performance

PISA 2006 used 13 test booklets, each with different combinations of items. Each science item was rated on the expected familiarity to a Third Year rJCSS student of the underlying competency and concept, and item ratings were combined to give average familiarity scores for each booklet. There were weak-to-moderate positive correlations between these scores and the PISA science scores of students who had completed the rJCSS (.12 for concept familiarity and .13 for competency familiarity levels). This means that students given a booklet with an above average familiarity score tended to do slightly better than those with a lower familiarity booklet.

Such low correlations may arise because few items were rated as unfamiliar to rJCSS students, meaning that booklet scores are very similar. However, when PISA science and curriculum science were last compared (Shiel et al, 2001), science achievement displayed far weaker correlations with the familiarity scales than either mathematics or reading. Thus, for science, familiarity with the concepts involved does not seem to be as important in explaining performance as is the case for mathematics and reading.

5 Reading and Mathematical Literacy

As described in Chapter 2, Ireland's mean score on the reading scale is 517.3, which is significantly higher than the OECD mean of 498.1, and 5th highest of OECD countries. On mathematics, Ireland's mean score of 501.5 (the 16th highest amongst OECD countries) does not differ significantly from the OECD mean of 497.7. In this chapter, performance on reading and mathematics is described in more detail. The proficiency levels of Irish students are compared to OECD averages, and gender differences and trends in Irish performance since 2000 are described. As both reading and mathematics were minor domains in 2006, data are available only for overall scales.

Reading Proficiency Levels

There are five reading proficiency levels as well as a "below level 1" category for students who cannot consistently demonstrate proficiency on even the most basic reading tasks in PISA. Table 5.1 summarises some of the main skills associated with each level. Unlike science, no sample reading items were released after the 2006 assessment. Readers who wish to examine sample reading items should refer to items released after PISA 2000. These can be accessed on *www.erc.ie/pisa.*

Table 5.1: Proficiency levels on the combined reading scale in PISA 2006, and percentages of students achieving each level (Ireland and OECD average)

Level Cut-point	At this level, a majority of students can ...	IRL		OECD	
		%	SE	%	SE
Level 5 Above 625.6	demonstrate full & detailed knowledge of a text, critically evaluate or hypothesize, drawing on specialised knowledge.	11.7	0.80	8.6	0.12
Level 4 552.9 - 625.6	show accurate knowledge of a long or complex text, combine multiple pieces of embedded information, and deal with ideas contrary to expectation.	25.1	1.04	20.7	0.17
Level 3 480.2 - 552.9	integrate multiple parts of a text to identify a main idea, deal with competing information, and evaluate a feature of text.	30.2	0.80	27.8	0.17
Level 2 407.5 - 480.2	construct meaning within a limited part of the text, make low-level inferences, and make basic connections between the text and outside knowledge.	20.9	0.93	22.7	0.17
Level 1 334.8 - 407.5	locate one or more pieces of explicitly stated information and recognise the main idea or author's purpose when the required information is pertinent.	9.0	0.84	12.7	0.15
Below Level 1 < 334.8	not respond correctly to more than 50% of Level 1 questions. Reading literacy is not assessed by PISA.	3.2	0.55	7.4	0.14

An average of almost 9% of students in OECD countries are classified at proficiency level 5, meaning that they can typically complete the most sophisticated reading tasks included in PISA. Ireland has significantly more students at this level (close to 12%) than the OECD average, but still lags far behind Korea (22% of students are at level 5), Finland (17%) and New Zealand (16%). In contrast, in "partner countries" such as Serbia, Romania, and Montenegro, less than a half a percent of students attain level 5.

Students classified at or below proficiency level 1 are those who do not reach baseline reading proficiency and are likely to have difficulty engaging in further study or in meeting the reading demands of society. The percentage of students failing to achieve baseline reading proficiency is much lower in Ireland (12%) than on average across OECD countries (20%). Ireland's performance compares very favourably with that of OECD countries such as Mexico, Turkey, Slovak Republic, Greece, Spain and Italy, where at least one quarter of students fall at or below level 1. At the other extreme, both Finland and Korea have fewer than 6% of students scoring below the baseline.

Gender Differences in Reading Literacy

In Ireland, female students obtained a significantly higher mean reading score (534.0) than males (500.2). This large gender gap in favour of females is also found in the OECD average means (511.2 versus 473.0). Females obtained significantly higher mean reading literacy scores than males in all participating countries.

On average among OECD countries, 6.2% of males and 11.0% of females were categorised at proficiency level 5. In Ireland, 8.7% of males and 14.6% of females reached proficiency level 5. At the opposite end of the spectrum, 25.8% of males and 14.2% of females in OECD countries were classified as not reaching baseline reading proficiency (i.e., at or below level 1). Students in Ireland fared somewhat better: 16.7% of males and 7.7% of females exhibited below baseline reading proficiency. There was considerable variation between OECD countries; over half of male students in Mexico did not reach proficiency level 2, compared to less than 2% of Finnish females.

Trends in Reading Scores

Reading was the major domain in the first PISA cycle, and all subsequent data are anchored in the 2000 scale. Ireland's mean performance in 2000 was 526.7 – significantly higher than the OECD average of 500.0. In 2003, Ireland's mean score dropped to 515.5. This was still significantly above the OECD mean, but represented a marginal drop from Ireland's performance in 2000 (significant at the 90% confidence level only). Ireland's low-achieving students performed at a similar level in the 2000 and 2003 assessments, while higher-achieving students (those scoring at or above the 75th percentile) did less well in 2003.

The overall means for Ireland are similar for 2003 and 2006, but there was a slight increase in the scores of students at the 95th percentile, meaning that very high-achieving students performed better in 2006. When performances in the 2000 and 2006 cycles are compared, the overall means are found not to differ significantly, and there are no significant differences in the scores of students at the key percentile markers.

A large number of OECD countries have seen a significant decline in performance between 2000 and 2006; declines of over 20 points have been recorded in Spain, Japan, Iceland and Norway. In contrast, both Korea (31 points) and Poland (29 points) have registered large improvements over the same period.

Mathematics Proficiency Levels

There are six mathematics proficiency levels, and a "below level 1" category for students who were unlikely to be able to demonstrate successfully the most basic mathematics skills that PISA seeks to assess. Table 5.2 summarises some of the main skills associated with each proficiency level. Readers who wish to view sample items and their difficulty levels should refer to items released after PISA 2003. These can be accessed on *www.erc.ie/pisa* and in the teacher guide to the 2003 mathematics results for Ireland (Shiel, Perkins, Close & Oldham, 2007). Ireland had proportionally fewer students (1.6%) at the highest proficiency level than the OECD average (3.3%). When performance at both levels 5 and 6 is considered, Ireland fares slightly poorer than the OECD average (approximately 10% of students versus an OECD average of 13%) and considerably poorer than countries such as Korea and Hong Kong-China, where over 27% reached at least level 5. Ireland also had 16% of students at or below level 1, better than the OECD average of 21%, but poorer than the roughly 9% of students so categorised in Korea and Hong Kong-China, and considerably poorer than Finland, where only 6% of students fail to reach level 2. These figures indicate that Ireland's overall average mathematics performance is attributable to lower-achieving students doing relatively well, and higher-achieving students doing comparatively less well.

Table 5.2: Proficiency levels on the combined mathematics scale in PISA 2006, and percentages of students achieving each level (Ireland and OECD average)

Level Cut-point	At this level, a majority of students can ...	IRL		OECD	
		%	SE	%	SE
Level 6 Above 669.3	evaluate, generalise & use information from mathematical modelling of complex problem situations.	1.6	0.25	3.3	0.09
Level 5 607.0 - 669.3	develop & work with mathematical models of complex situations.	8.6	0.67	10.0	0.12
Level 4 544.7 - 607.0	work with mathematical models of complex concrete situations.	20.6	0.94	19.1	0.16
Level 3 482.4 - 544.7	work in familiar contexts usually requiring multiple steps for solution.	28.6	0.90	24.3	0.16
Level 2 420.1 - 482.4	work in simple contexts that require no more than direct inference.	24.1	1.00	21.9	0.17
Level 1 357.8 - 420.1	work on clearly defined tasks with familiar contexts where all relevant information is present and no inference is required.	12.3	0.93	13.6	0.15
Below Level 1 < 357.8	not respond correctly to more than 50% of Level 1 questions. Mathematical literacy is not assessed by PISA	4.1	0.50	7.7	0.14

Gender Differences in Mathematical Literacy

In Ireland, males (507.3) outperform females (495.8) on mathematical literacy. This is very similar to the OECD average difference (503.2 versus 492.0, a difference of 11.2 points in favour of males). Twenty-two of the 30 OECD countries had a gender difference favouring males, the largest being an almost 23-point gap in Austria. Qatar was the only participating country where a significant gender difference favouring females was found.

Only 0.9% of females in Ireland were classified at proficiency level 6, compared to 2.4% of males (OECD equivalent percentages are 2.5% for females and 4.2%, for males). Only 8.3% of Irish females demonstrated level 5 or 6 mathematics proficiency, compared to 12.3% of males. Although mirroring the direction of gender differences internationally, the Irish percentages for high achievers (levels 5 and 6) are below the OECD averages of 11.2% of females and 15.5% of males.

At the other end of the proficiency scale, Ireland has proportionally fewer lower-achieving males and females than the average in OECD countries. While an OECD average of 20.4% of males were classified at or below level 1, the equivalent percentage for Ireland is 15.4%. For females, 17.3% failed to attain level 2 in Ireland, compared to an OECD average of 22.2%.

Trends in Mathematical Literacy

Trend analyses for mathematics are somewhat limited, as only changes from the baseline cycle of 2003 can be examined. Ireland's average scores for mathematics in 2003 and 2006 are very similar. The small drop of 1.4 points in 2006 is non-significant.

Amongst OECD countries, the most notable decrease in mean mathematics scores was seen in France, Iceland and Japan (French students averaged 15 points lower in 2006 than in 2003), while the most notable improvements were found in Greece (an increase of 14 points) and Mexico (20 points). In Ireland, and for the OECD average, there was a slight drop in scores at the 75th, 90th and 95th percentiles. However, while the changes are significant at the OECD level, they are not for Ireland.

6 Attitudes to Science

Students' attitudes to science were assessed in two ways in PISA 2006: through questions on the Student Questionnaire, and through questions embedded in the science test booklets. Sets of related attitude questions were combined to establish attitudinal indices – usually with an OECD average of 0, and a standard deviation of 1. This chapter looks at attitudinal indices that, according to OECD (2007), are comparable across cultures because they relate to science achievement in a systematic way both within and between countries, and, for Ireland only, at indices that are not. It also looks at attitudinal scales based on questions embedded in the science test. Readers should be aware of the interrelated nature of many of the attitudinal indices presented, and of their association with achievement. Furthermore, a variable such as self-efficacy in science can be viewed as a schooling outcome in its own right, and may have a reciprocal relationship with achievement.

Attitudes Comparable Cross-Culturally

On an index assessing student *awareness of environmental issues*, students in Ireland had the highest mean score (0.38) among OECD countries. Compared to the OECD average, greater proportions of students in Ireland indicated familiarity with issues such as deforestation, acid rain, greenhouse gases (e.g., Ireland: 75.0%, OECD: 58.4%), and nuclear waste. However, only 26.0% of students in Ireland reported familiarity with the use of genetically modified organisms, compared to the OECD average of 35.0%. In Ireland, the correlation between the index and science achievement is 0.42, which is close to the average across OECD countries (0.45).

The Irish mean score of 0.02 on the index of *general value of science* is almost identical to the OECD average. Typically, there was a very high level of agreement (in Ireland and across OECD countries) with statements relating to the contribution of science and technology to understanding the natural and constructed world, and to improving economic and social conditions. Agreement was lowest for the belief that "advances in science usually bring social benefits" (66.6% of students in Ireland and 75.0% across OECD countries). In Ireland, the correlation between *general value of science* and achievement is 0.33. On average across OECD countries, it is 0.29.

Self-efficacy in science or confidence in one's ability to solve science problems was measured by asking students to indicate the ease with which they could perform each of eight science-related tasks. For example, 55.0% of students in Ireland said they could easily or with some effort describe the role of antibiotics in treating disease. The mean score of students in Ireland on the index (0.01) was close to the OECD average. The correlation between *self-efficacy in science* and science achievement is stronger in Ireland (0.45) than the average in OECD countries (0.39). On each of the three indices, males in Ireland and on average across OECD countries scored significantly higher than females. For each index, the difference in Ireland was small (about one tenth of a standard deviation).

National Attitudinal Indices

Irish data for attitudinal indices that were unsuitable for cross-country comparisons are summarised in Table 6.1. The indices most strongly correlated with science achievement are *enjoyment of science* (0.40) and *self-concept in science* (0.39). *Optimism regarding environmental issues* is negatively correlated with achievement (i.e., higher-achieving students tended to be pessimistic). Females obtained higher values than males on six indices (including *responsibility for sustainable development*) while males obtained higher values on three (including *self-concept in science*).

Table 6.1: Summary characteristics of national attitudinal indices

Index Name	Sample content & percent endorsing	Gender difference on index	Corr. with science ach.
Enjoyment of science	Generally have fun learning science topics (48.1%)	No difference	.40
Self-concept in science	Easily understand new ideas in science (51.4%)	Males higher	.39
Personal value of science	Will use science in many ways when an adult (60.8%)	Females higher	.34
Instrumental motivation to learn science	Study science because I know it is useful for me (73.0%)	Females higher	.28
Responsibility for sustainable development	Favour laws to regulate factory emissions, even if prices increase (60.8%)	Females higher	.32
Future-orientated motivation to learn science	Like to study science after secondary school (35.9%)	Females higher	.31
General interest in science	Interest in physics topics (40.8%), chemistry (43.5%), human biology (76.9%)	Females higher	.34
Engagement in science-related activities	Regularly/often watch TV programmes about science (17.6%)	Males higher	.26
Concern for environmental issues	Serious concern for me and others: air pollution (89.1%); water shortages (67.0%)	Females higher	.04
Optimism regarding environmental issues	Problems related to energy shortages will improve over next 20 years (25.6%)	Males higher	–.18

Although the index *engagement in science* is not designed for cross-national comparison, we can use cross-national comparisons for frequency of responses to its constituent parts. Doing so reveals a very low level of engagement in science-related activities among students in Ireland. For example, the percentages of students in Ireland who reported that they regularly or often read a science article, accessed a science website, or watched a TV programme about science are below the OECD average. Only Japanese students reported lower participation in science-related activities.

Scales Based on Embedded Attitudinal Items

Two attitudinal scales, *interest in learning science topics* (e.g., interest in effects of herbicides on plants) and *support for scientific enquiry* (e.g., support for the systematic study of fossils) were developed from items "embedded" in the science test. While males in Ireland obtained significantly higher scores than females on *support for scientific enquiry,* there is no gender difference on *interest in learning science topics*. The correlation between *support for scientific enquiry* and science performance is 0.41, while that between *interest in learning science topics* and science performance is just 0.14.

7 Factors Linked to Achievement

This chapter relates some student- and school-level factors to student achievement. The analyses reported are *univariate*, describing how a single independent variable relates to the dependent variable of achievement. Clearly, such analyses do not take account of the fact that many factors associated with achievement are themselves interrelated. More complex, multivariate analyses will be included in the forthcoming main Irish national report of PISA 2006, to be published in April 2008. Performances in the three PISA assessment domains are highly inter-correlated and tend to have similar relationships with explanatory variables (a notable exception is gender, which was discussed in Chapters 3 and 5). Thus, the analyses in this chapter will focus on associations with scientific literacy.

Student Background Characteristics

The PISA index of ESCS (Economic, Social and Cultural Status) is an amalgam of parental education and occupation, as well as resources in the home, all of which, individually, have been found to relate to achievement. It is scaled to an OECD mean of 0 and a standard deviation of 1. In 2006, Ireland's mean score (-0.02) was almost identical to the OECD mean. Ireland is just above the OECD average on the occupational element of the scale, but well below average on cultural and educational resources in the home (e.g., 26th of 30 OECD countries on cultural resources). ESCS scores account for 12.7% of variation in science test scores in Ireland, compared to an OECD average of 14.4%. A weak association between background and achievement is sometimes interpreted as indicative of a more equitable education system.

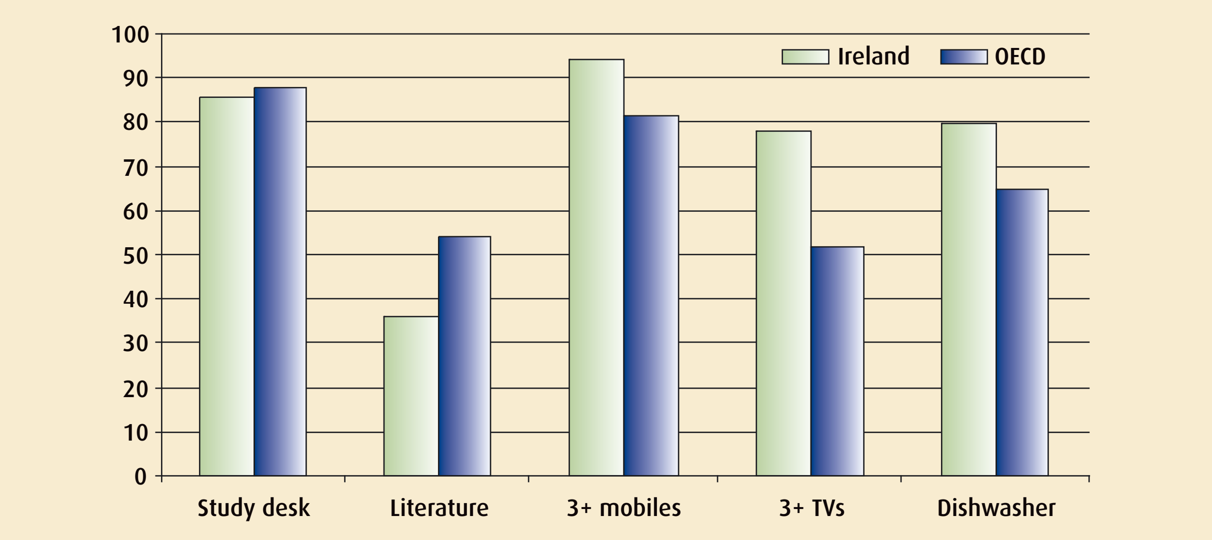
Students in Ireland were asked a number of extra questions relating to their engagement in work, family size, and interactions with their parents. Family size and science achievement are closely related: the mean score (466.7) obtained by the 4.6% of students with six or more siblings is well below the mean of 522.5 obtained by students with one sibling. There was also a clear relationship between frequency of student-parent interaction and achievement. For example, students who regularly discussed books or films, or spent time just chatting with their parents, tended to obtain above average science scores. The relationship was most pronounced for students who discussed politics and social issues with their parents. There was a 63-point gap between the mean score of those who rarely or never discussed politics and social issues with their parents (484.3) and the mean score obtained by those who did so several times a week (547.2). However, socioeconomic status may be a confounding variable in these relationships, as students with high ESCS scores reported higher levels of student-parent interaction than students with low ESCS scores.

On average, students spent 5 hours 23 minutes per week in paid work, 3 hours 25 minutes in unpaid work, and 8 hours 28 minutes total hours worked. There was a weak negative correlation between amount of unpaid work and achievement (–.01). Achievement was weakly-to-moderately correlated with total hours worked (– .12) and with amount of paid work (– .15 overall, but stronger for males [–.19] than females [–.11]).

Students were asked about types of resources they had at home. For each education-related resource, possession was associated with higher achievement scores. While some resources (calculators, educational software and internet access) were more common in Ireland than was the norm in OECD countries, others were less commonly found here (literature, poetry, a desk, and a quiet place to study).

Irish students were well above the OECD average on almost all affluence indicators (e.g., mobile phones, dishwasher, TVs, DVD players, cars). While some affluence indicators were positively related to achievement, indicators involving TV showed a different pattern. Students with three or more TVs in their home scored significantly lower (504.4) than students with one TV (535.8). Likewise, students with access to a premium cable TV package averaged a poorer science score (498.9) than students without access (527.5). Figure 7.1 offers selected comparisons of the availability of resources in Ireland compared to the corresponding OECD average.

Figure 7.1: Percentages of students (Ireland and OECD average) reporting the availability of various resources and affluence indicators in their homes



Reflecting the OECD average, just over one in ten students in Ireland reported having between zero and 10 books in their home, while, at the other end of the scale almost 9% (Ireland and OECD) reported having more than 500 books. There is a very clear relationship between the number of books in the home and achievement. Students in Ireland who had 10 or fewer books in their home obtained an average achievement score of 434.3, while students with 500 or more averaged 551.3 (a very large difference).

The Student in School

Students taking the Transition Year programme obtained the highest scores on each of science, reading and mathematics, followed by students in the Leaving Certificate programme (Table 7.1). Lowest scores on each domain were obtained by the small percentage of students taking the Leaving Certificate Applied programme (e.g., 425.2 for science). Students taking the Leaving Certificate Vocational programme averaged slightly lower scores than students taking the traditional Leaving Certificate, but the difference was significant only for mathematics. However, the programme a student was enrolled in was closely linked to ESCS. Transition Year students averaged higher scores on ESCS than students on any of the other programmes, while Leaving Certificate Applied students averaged lower scores. Thus, the association between achievement and programme type may, at least in part, be explained by socioeconomic factors.

Table 7.1: Mean scores on each PISA domain, by study programme

		Science		Reading		Maths	
	%	Mean	SE	Mean	SE	Mean	SE
Junior Certificate	62.0	495.1	3.65	502.9	3.99	488.7	3.07
Transition Year	21.1	537.1	4.33	547.8	4.70	530.1	4.30
Leaving Cert. Applied	1.2	425.2	14.93	456.5	12.40	442.4	12.42
Leaving Cert. Established	12.3	530.2	5.17	539.1	5.54	522.6	4.81
Leaving Cert. Vocational	3.3	515.8	8.18	528.4	9.60	496.9	7.29

Information on whether or not a student had taken science in the Junior Certificate Examination was available for approximately 94% of students (Table 7.2). Higher level students obtained a mean PISA science score of 550.9, far higher than the 441.1 obtained by students who took Ordinary level or the 444.0 obtained by those who had not studied science at either level. The 3-point difference in the mean scores of students who took Ordinary level and those who did not study science is not significant[9].

Table 7.2: Mean science scores, split by uptake of Junior Certificate science

	%	Mean	SE
JC science: Higher	62.1	550.9	2.50
JC science: Ordinary	26.4	441.1	3.42
Did not study JC science	7.9	444.0	6.86
Missing data	3.6	426.2	12.61

There were also differences between students who had sat the Junior Certificate Examinations in 2005 and 2006. The 2006 cohort (most of whom would have studied the rJCSS) obtained significantly lower mean scores than students who sat the Junior Certificate in 2005. For example, among students who took Higher level Junior Certificate science, those who sat the examination in 2005 obtained a mean score of 564.0, which is 22 points higher than the mean of 542.0 obtained by the 2006 Higher level science students. However, it is likely that much, if not all, of this difference is attributable to a grade effect, rather than to the effects of the syllabus. Students are not randomly assigned to grades: the 2005 cohort have not only experienced an additional year of schooling, but are also likely to be a year ahead because they differ academically. The grade effect becomes clearer when we examine the performance on PISA science of students who did not study Junior Certificate science (i.e., where no effect can be attributable to syllabus). The 2005 cohort obtained a PISA science mean of mean of 471.6, which is 45 points higher than the mean of 427.0 obtained by the 2006 cohort.

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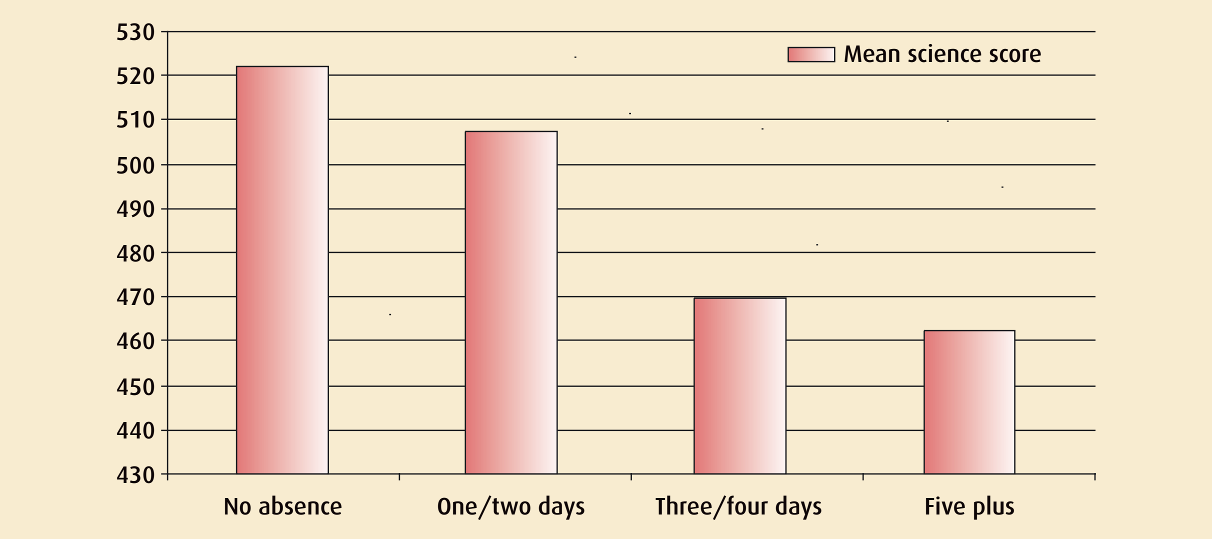
[9] On each domain, Higher level Junior Certificate science students obtained significantly higher means than Ordinary level students and students who did not take Junior Certificate science. The latter two groups did not differ significantly from each other on any domain.

Almost half (43.4%) of students in Ireland reported that they had experienced some form of bullying during the school term in which PISA took place. Rates were similar for different types of school (e.g., fee-paying, designated disadvantaged, mixed or single sex, sector) and for males and females. Most who reported being bullied had experienced more than one form of bullying, such as name-calling, or being physically hurt. Students who had not been bullied averaged the highest score on the science scale (522.4); students who had been bullied in four different ways had the lowest average score (477.2). While a drop in mean scores was apparent for females once one form of bullying was reported, the effect for males was more gradual, with a noticeable decline in performance only occurring once four or more forms of bullying were reported.

Students who reported that they planned to complete a Leaving Certificate programme obtained a higher mean score on the science test (518.2) than the 8% who were unsure about their plans (436.9) and the almost 2% who planned to leave school before the Leaving Certificate (413.8). Absenteeism was also related to achievement. A higher number of absences in the fortnight preceding the PISA assessment day was associated with lower achievement (e.g., an average score of 521.7 for students who had not missed any days, compared to a score of 462.7 for students who were absent for at least a week) (Figure 7.2).

Figure 7.2: Mean scores on the overall science scale by number of days absent in the two weeks preceding the assessment



School Characteristics

The schools that participated in PISA were quite representative of schools nationally. For example, 60% of students in the sample were in secondary schools, one quarter in schools designated as disadvantaged, and 36% in schools located in Dublin or the surrounding area. Just over 93% were taught entirely through the medium of English, only 6% were in schools that accepted boarders, and 6% were in fee-paying schools. The average size of school was 546.4 students, with enrolments ranging from 89 to 1,540 students. There was a weak-to-moderate positive correlation (r = .16) between school size and performance on the science assessment, meaning that students in larger schools tended to perform slightly better. The correlation was stronger in all-male schools (r=.26) than in mixed-sex schools (r= .16), and was very weak in all-female schools (r= .04).

Performance on the science test varied significantly by sector. Secondary school students had the highest mean score (521.3), significantly higher than the means obtained by students in vocational schools (480.7), or community and comprehensive schools (501.3) (Table 7.3). The OECD analysis of PISA 2006 data groups schools into government-independent and government-dependent. This categorisation depends on funding and management structure (OECD, 2007). In Ireland it roughly translates as secondary schools versus all other school types. As in most countries, students in secondary/independent schools obtain higher mean science scores. However, the advantage disappears when account is taken of student and school ESCS.

Table 7.3: Mean science score by school type

Sector	%	Mean	SE
Community & Comp	16.8	501.3	6.47
Secondary	59.6	521.3	3.69
Vocational	23.6	480.7	7.09

The one-quarter (25.2%) of students who attended schools designated as disadvantaged obtained a significantly lower mean science score (479.8) than students in non-designated schools (517.9). Students in single-sex schools obtained significantly higher mean scores than students in mixed-sex schools, but this is largely accounted for by mixed-sex vocational schools. There are no significant differences by gender composition in secondary schools.

Students in schools that accepted boarders or that were fee-paying obtained significantly higher mean scores than students in other types of schools (e.g., a mean of 564.3 for fee-paying schools versus 504.9 for other schools). However, home background may again be a factor here. For example, the average ESCS of students in fee-paying schools is a full standard deviation above the national average. Thus, it is possible that at least some of the superior performance of students in such schools is due to student background characteristics, rather than characteristics of the schools in and of themselves.

System Characteristics

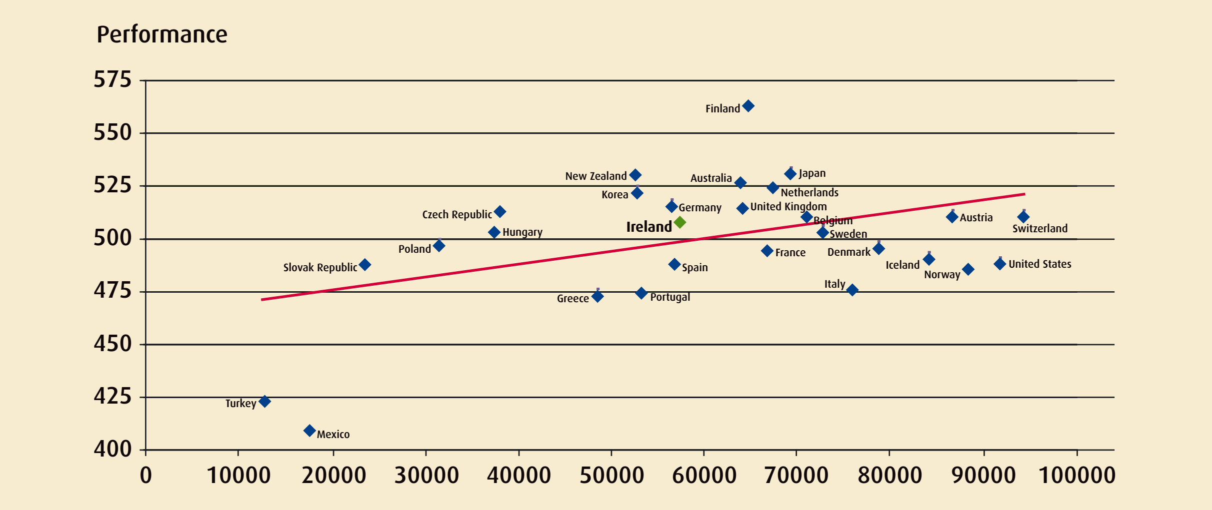
In Ireland, 17% of variance in science test scores is attributable to differences between schools, compared to an OECD average of 34%. A contrasting example is Germany, where 66% of variance is "between school variance". These data suggest that schools in Ireland tend to be similar to each other, with considerable variety *within* schools. In contrast, German schools tend to be quite dissimilar, with far less variety within schools, a result of splitting students into separate types of post-primary school.

OECD analyses indicate that countries with higher national income (measured by gross domestic product (GDP) per capita) tend to perform better in science, and that 28% of the variation between OECD countries' mean scores can be predicted on the basis of their GDP per capita (OECD, 2007). Ireland's performance on PISA science is more or less what would be predicted on the basis of per capita GDP. In some countries, such as the US, performance is poorer than would be expected on the basis of GDP, while in Finland and New Zealand, it is better. A country may be wealthy, yet invest comparatively little in education. Figure 7.3 is taken from the international PISA report (OECD, 2007) and charts countries' average spending per student (ages 6 to 15) against average science performance. Data in the Figure are based on *purchasing power parities*, a measure that provides cross-country comparisons that take into account factors such as differences in cost of living and services. Ireland is located towards the lower half of the chart, indicating an average investment that is slightly less than the OECD average.

The "trend line" shows the expected relationship between spending and achievement. Achievement tends to increase with spending, but the relationship is not particularly strong, and spending per student explains only 19% of the variation in mean performance between the countries shown. Ireland is located close to the trend line, indicating that performance is what might be expected based on level of investment in education. Some countries are quite a distance from the line, indicating that their educational spend is not as good a predictor of achievement as in other countries. For example, Finland invests roughly the same amount per student as Australia and the UK, yet has a much higher level of achievement. Norway and the US are among the highest spenders, yet their mean levels of achievement are similar to that in the Slovak Republic (which is among the lowest spenders).

Much of the variation explained is due to Turkey and Mexico, both of which have levels of expenditure and achievement well below the OECD average. Removing these two countries from analyses reduces to non-significance the relationship between spending and achievement. This indicates that the relationship between spending and achievement is quite complex. While a certain minimum expenditure level seems to be required, spending alone will not guarantee high achievement.

Figure 7.3 Student performance on the science scale and cumulative expenditure per student (from age 6 to 15) expressed in US Dollars, using purchasing power parities



Adapted from OECD (2007), Figure 2.12b

8 Interpreting the Results

In this chapter, we summarise some of the main findings from PISA 2006, and discuss implications.

Overall Results

Irish students' best performance was on reading literacy, where the Irish mean score of 517.3 was well above the OECD mean of 491.8. This performance placed Ireland 5th among OECD countries (indicating a "true" rank of between 4th and 6th). Performance on science (the major domain) was also slightly, but significantly, above the OECD average (508.3, compared to the OECD mean of 500.0). Ireland ranks 14th of OECD countries on the science assessment. For mathematics, Ireland's mean score of 501.5 does not differ significantly from the OECD mean of 497.7, giving it a rank of 16th. Ireland's "true ranks" for science and mathematics are between 10th and 16th, and 12th and 17th, respectively.

In sum, Ireland's students performed very well on the reading assessment, reasonably well on science, and about average on mathematics. This pattern was also evident in both previous PISA studies, and is in contrast to countries such as Finland, Hong Kong-China and Canada, where performance is well above average on all three domains. PISA science has a reasonably high reading load, and the correlation between achievement on science and reading is .86. Thus, it is possible that the above average reading literacy levels among Irish students (and students in countries such as Finland and Canada) will have provided them with a slight advantage on aspects of the science test.

Scientific Literacy

Ireland's performance on the overall science scale is above the OECD country average, albeit by a small margin. Our ranking in 2006 is reasonably similar to 2000 and 2003. Many aspects of performance on science are encouraging. For example, Ireland has proportionally fewer students failing to reach proficiency level 2 on the overall science scale and on each of the science competency scales than the averages in OECD countries. Level 2 is the "baseline" proficiency level, meaning that students falling below this level are likely to have great difficulty participating in real life situations that involve science or technology and in future education (OECD, 2007). Ireland is very similar to the OECD average in terms of the percentage of students scoring at the higher proficiency levels. This suggests that Ireland's slightly above average performance on science is not attributable to a large group of high-achieving students, but to the fact that we have proportionally fewer students with only minimal scientific literacy. It also suggests that there is room for improvement among higher-performing students.

Students in Ireland were reasonably consistent in performance across the science subscales, and obtained mean scores that were at least as high as the OECD average on all subscales. Thus, there is no area in which Ireland's performance can be classified as weak. Students showed a relative strength in *identifying scientific issues* (515.9), scoring 17 points above the OECD mean (largely due to a high score among females relative to males on the subscale).

In Ireland, and in most OECD countries, overall science scores of males and females were similar, but differences were in evidence on subscale performance. Females in Ireland performed very well (523.9) on *identifying scientific issues*. They were also well above average on *knowledge about science* (517.2) while males did best on *knowledge of science* subscales. In particular, males did relatively well on *knowledge of Earth and space systems* (515.2) and *knowledge of physical systems* (516.0). Broadly speaking, females in Ireland are good at understanding the nature of science, and understanding scientific enquiry and explanations, while males seem to be better at understanding scientific facts and topics and applying them to everyday situations. An awareness of such gender differences could prove helpful to science teachers, once it is realised that these are *average*, not absolute, gender differences.

PISA Science and Junior Certificate Science

The fact that Ireland's science ranking in 2006 is similar to that in 2000 and 2003 suggests that the revised Junior Certificate Science Syllabus (rJCSS) has not yet led to any discernible improvement in students' science achievement. Since the conceptualisation of science in the revised syllabus is closer than its predecessor to the PISA view of science, and the PISA definition of scientific literacy is included in the rationale for revision (Department of Education and Science, 2003), it is somewhat disappointing that performance on PISA has not improved. However, it must be noted that approximately half of PISA participants had not followed the revised syllabus (see footnote 8), and that some of the syllabus implementation difficulties highlighted by Eivers et al (2006) may have curtailed effects on performance in PISA. It might also be noted that few students in PISA 2006 had experienced the new Primary School Science Curriculum, which was first implemented in 2003. Thus, effects (if any) on PISA scientific literacy from the new primary curriculum would not yet be apparent.

The introduction of the rJCSS appears to have led to a closer alignment between PISA science and science as experienced in Irish schools, although many differences remain. There has been a marked change in the percentage of PISA items addressing topics familiar to Junior Certificate science students. When PISA and Junior Certificate science were last compared, 43% of science items were considered to deal with topics that were not included in the syllabus, while close to half were judged to be based on concepts unfamiliar to students following the Junior Certificate syllabus (Shiel et al, 2001). In the 2006 science assessment, only 16% of items could not be located somewhere within the revised syllabus, and only 4% were considered to be based on concepts that were unfamiliar to students. In light of these findings, it is rather surprising that there was no evidence of improvement in student performance in Ireland.

Reflecting the findings of PISA 2000, only a weak relationship was found between student familiarity (as rated by syllabus experts) with the PISA science items encountered in their test booklet and test performance in 2006. In the present study, this may in part be because so few items were rated as unfamiliar that all test booklets received a high familiarity rating. Of course, it may also suggest that the PISA science assessment is assessing real-life science, as opposed to what is learned in the curriculum. In this regard, we can examine student performance on aspects of PISA that receive limited coverage in the rJCSS assessment. For example, *identifying scientific issues* is the PISA science competency that was adjudged to receive the least amount of marks in the assessment of the 2006 Junior Certificate, yet it was the competency on which students in Ireland performed best.

However, the skills central to *identifying scientific issues* are fundamental to the investigative approach espoused by the rJCSS, and would have formed part of the curriculum experienced, if not explicitly examined, in 2006. In a related vein, students in Ireland performed significantly above the OECD average on *knowledge of Earth and space systems*, despite very little coverage on the syllabus. However, many may have drawn on the geography syllabus for this element of the assessment.

In relation to the overlap between PISA and the rJCSS, it is important to note that while there is greater overlap than in the 2000 assessment, PISA 2006 did not assess significant parts of the science curriculum for Junior Certificate students in Ireland. We have already referred to the under-representation of chemistry in PISA items. However, section 1B of the rJCSS (which deals with genetics and the muscular, sensory, skeletal and reproductive systems) is not represented by *any* PISA items. While it is impossible to provide in-depth coverage of all the main branches of science, it is ironic that an assessment of real-life science ignores the development of life itself.

Reading Literacy

In PISA 2003, students in Ireland performed marginally less well in reading than in 2000, albeit on a subset of the items used in 2000. The small but marginally significant decrease may have been due to technical difficulties with a small number of items (see Shiel, 2006). The slight improvement in reading from 2003 to 2006 is not significant, but it is sufficient to ensure that the gap between the 2000 and 2006 scores for reading is not significant.

In 2006, fewer students in Ireland (12%) than across OECD countries (20%) achieved at or below Level 1, while more students in Ireland (12%) achieved at Level 5 (OECD average = 9%). Countries such as Finland and Korea have considerably fewer students than Ireland at or below level 1, and more at Level 5. The stronger representation of female students at level 5 in Ireland, and their under-representation at level 1, suggest a need to improve performance among male students in particular, although it must be recognised that gender differences in reading literacy arise for a variety of reasons, including the particular combination of text and item types that are assessed and low engagement in reading among males (Shiel, 2006).

A recent report by the Department of Education and Science inspectorate (2006) recommended strategies that schools could use to raise standards in reading and other aspects of English. These include structural changes (postponing ability grouping until the end of Second year at the earliest), better use of equipment and resources, more collaborative and continuous planning, assessment practices that provide more focused feedback, and raising teacher expectations of lower achievers. While endorsing the recommendations, we suggest that schools need support not only in implementing changes, but also in evaluating actual effects on practice and the impact, if any, on achievement. The proposed extension of the Junior Certificate School Programme under the DEIS initiative (Department of Education and Science, 2005) should also be evaluated for its effects on reading literacy.

Mathematical Literacy

Mean performance on PISA mathematics has not changed significantly since it was a major assessment domain in 2003. While fewer students in Ireland scored at or below level 1 on the PISA 2006 mathematics proficiency scale compared with the OECD average (16% versus 21%), fewer also performed at or above Level 5 (10% versus 13%). Hence, it seems that lower achievers in Ireland are doing comparatively well, but that higher achievers could do better. It should be noted that Junior Certificate mathematics is unusual, because it is one of only two Junior Certificate subjects (Irish being the other) for which a minority of candidates opt for the Higher level syllabus. It would be interesting to examine the effects, if any, on performance on PISA mathematics as a result of increased uptake of Higher level mathematics. Although there was a small drop in the mean score of male students in Ireland in PISA 2006 mathematics (compared with 2003), they outperformed female students.

The significant philosophical and content differences between PISA and Junior Certificate mathematics (Cosgrove et al., 2005; Conway & Sloane, 2005) may account, at least in part, for the moderate performance of students in Ireland in PISA mathematics. Close and Oldham (2005) have contrasted the PISA focus on mathematics as it occurs in real-life with the mathematics programme as typically taught in Irish post-primary schools (which tends to be quite abstract and formal, with little emphasis on the application of mathematics). The aims of the curriculum include the application of mathematics. However, the relative under-emphasis on an applied approach in the *assessment* of mathematics – i.e., on the Junior Certificate Examination – appears to exert a stronger influence on the curriculum as implemented.

The outcomes of a review of post-primary mathematics by the National Council for Curriculum and Assessment (e.g., NCCA, 2006) have resulted in proposals for Project Maths – a curriculum development project that, in time, should lead to syllabus change with increased emphasis on problem-solving skills, and context and application (NCCA, 2007). Ideally, the effects of such change will be evident in improved performance on PISA 2012, when mathematics is the main assessment domain.

Attitudes to Science

Students in Ireland recorded the highest mean score on awareness of environmental issues, and also reported a positive general attitude to science, findings that are consistent with those reported by the Task Force on the Physical Sciences (2002). Although we cannot infer causal relationships between constructs such as self-efficacy or self-concept and science performance, there may be some value in exploring how these dispositions can be nurtured in tandem with improvement in performance. The relatively low levels of engagement by students in Ireland in science-related activities such as watching TV programmes about science or accessing a science website may have implications for the design of learning activities in science curricula, where there may be some value in broadening the range of activities encountered. Concern must be expressed about levels of interest among 15-year-olds in Ireland in physics and chemistry, which are considerably lower than for human biology.

Factors Linked to Achievement

Many student factors were associated with science performance. For example, in Ireland, student economic, social and cultural status (ESCS), number of books in the home, other home resources, and certain characteristics of schools were all associated with science performance. On average, females outperformed males on reading literacy, males outperformed females on mathematics, and there were no gender differences in overall scientific literacy.

The link between ESCS and achievement is slightly weaker in Ireland than the OECD average, and Ireland's mean on the ESCS scale is also just below average (largely due to lower than average levels of cultural and educational resources in the home). If we examine changes in level of home resources in Ireland since PISA 2000, no change is discernible in most educational or cultural resources (e.g., a study desk or poetry books), but there have been large increases in affluence indicators, such as dishwashers, computers, and multiple TVs. PISA 2006 reaffirms the positive association between number of books in the home and science performance and reveals poorer achievement for students with three or more TVs at home. It may be considered unfortunate that the latter has increased since 2000 while the former remains unchanged.

As in both previous PISA studies, students who had not taken Junior Certificate science did not differ significantly in average science achievement from students who took the subject at Ordinary level. Further, in 2006 there were no significant differences between the two groups on mean PISA reading or mathematics scores. Given their similar reading and mathematical literacy levels, Ordinary level science students might have been expected to outperform non-science students on science. The fact that they do not suggests that Ordinary level science does not provide them with any additional knowledge of science (as measured by PISA) and therefore raises the question of what scientific skills and knowledge the course does provide, and what PISA assesses.

Lower mean scores were found among students who had a part-time (paid) job, who had been absent from school for at least some of the fortnight preceding the assessment, and among students who had been bullied. Indeed, levels of absenteeism may have been under-reported by Irish students in PISA as 13% were absent on the day(s) on which PISA was administered in their schools. Apart from any negative effects the bullying of students may have on student achievement, our findings indicate the presence of a widespread problem (43% of students reported being bullied in the school term in which PISA took place) across all school types that needs to be addressed.

School-level variables associated with science performance include sector (secondary school students significantly outperformed students in other types of schools), designated disadvantaged status (students in non-designated schools did better), gender composition (students in single-sex schools outperformed those in mixed schools), size (students in larger schools did slightly better) and socioeconomic and cultural status (higher average ESCS in a school was associated with higher achievement). However, in almost all cases, ESCS was a confounding variable. For example, initial OECD analyses suggest that the advantage found in secondary schools is largely accounted for by student ESCS and by average school ESCS. Thus, it may be that many of the “advantages” perceived to attach to certain school types reflect, among other things, “advantages” students bring to the school.

Although we can compare differences in average achievement of different categories of school, differences in Ireland are small relative to the OECD average (between-school variance in Ireland is 17%, compared to an OECD average of 34%). This may reflect the common academic curriculum in schools in Ireland, and the fact that students are not assigned to vocational or academic tracks at an early stage in their development. However, between-class variance can be quite large, possibly because of practices in some schools of assigning students to class groups based on ability.

The amount of money each country spends on education is related to achievement, but the relationship is much weaker than might be expected. The performance of Irish students on the science test is close to what would be predicted, based on spending on education. New Zealand and Korea, however, spend less than Ireland, yet mean science achievement in these two countries exceeds Ireland's mean. In contrast, the US and Norway spend considerably more than Ireland, yet their mean science performance is significantly poorer. This indicates that the relationship between expenditure on education and educational achievement is quite complex.

Summary of Main Findings

The performance of students in Ireland in PISA 2006 was broadly similar to performance in PISA 2003, with a mean score in reading literacy that was well above the OECD average, a mean score in overall science that was just above average, and a mean score in mathematics that was average. Ireland's students scored above average on just one of three science competencies assessed (*identifying scientific issues*). The findings suggest Ireland has relatively few students with minimal scientific literacy, but that there is room for improvement among higher-performing students. While male and female students in Ireland did not differ on the overall science scale, there were differences on key science competencies and knowledge areas.

Students who took Higher level science in the Junior Certificate Examination outperformed students who took Ordinary level, while the latter group did not differ from students who had not taken science. Other student-level variables associated with science achievement include attitudes towards science; elements of the home environment such as educational resources, interaction with parents, and parental socioeconomic status; experience of bullying; and engagement in paid work during school term. School-level variables linked with achievement include school size, type, designated disadvantaged status and gender composition. Between-school variance in achievement in Ireland was low relative to the OECD average.

The full national report on PISA 2006, to be published in April 2008, will include a more detailed analysis of performance and of variables associated with performance. Analyses will include multi-level models of achievement in scientific, mathematical and reading literacy designed to clarify relationships among variables associated with performance in PISA.

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Appendix A

Sample Items and Item Statistics

This appendix contains a sample of science items used in PISA 2006. The items were released after the assessment was completed and will not be used in future cycles. No new mathematics or reading items were released following the 2006 assessment. Readers who wish to review additional science items or mathematics or reading items released in previous cycles can access them on *www.erc.ie/pisa* or *www.oecd.org/pisa.*

The formatting of items has been altered slightly in order to reduce the amount of space required. Thus, while the content shown is that encountered by students, the layout is slightly different. For each item, we have included the percentage of correct responses (Ireland and OECD) and an indication of the response required. Also included is the score on an item difficulty scale (similar to the achievement scales, with a mean of 500 and a standard deviation of 100) and the proficiency level at which the item is located.

Table A1 summarises some features of the sample items. Six items from two units[10] are presented. The items represent a mixture of item types, competencies and categories of *knowledge of* or *knowledge about science*. For example, Greenhouse question S114Q03 is an open response item framed in a global context, and assesses the student's competency at *using scientific evidence* while also examining *knowledge of scientific explanations*.

Table A1: Summary of sample item classifications

Unit name	Item code	Item type	Context	Competency	Knowledge of/about
Greenhouse	S114Q03	Open response	Global	Using scientific evidence	Scientific explanations
Greenhouse	S114Q04	Open response	Global	Using scientific evidence	Scientific explanations
Greenhouse	S114Q05	Open response	Global	Explaining phenomena scientifically	Earth and space systems
The Grand Canyon	S426Q07	Complex multiple choice	Social	Identifying scientific issues	Scientific enquiry
The Grand Canyon	S426Q03	Multiple choice	Social	Explaining phenomena scientifically	Earth and space systems
The Grand Canyon	S426Q05	Multiple choice	Social	Explaining phenomena scientifically	Earth and space systems

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[10] PISA items are grouped into *test units*, composed of a stimulus (text or text plus a visual representation such as a graph or table) and up to five items related to the stimulus.

Greenhouse

Read the texts and answer the questions that follow.

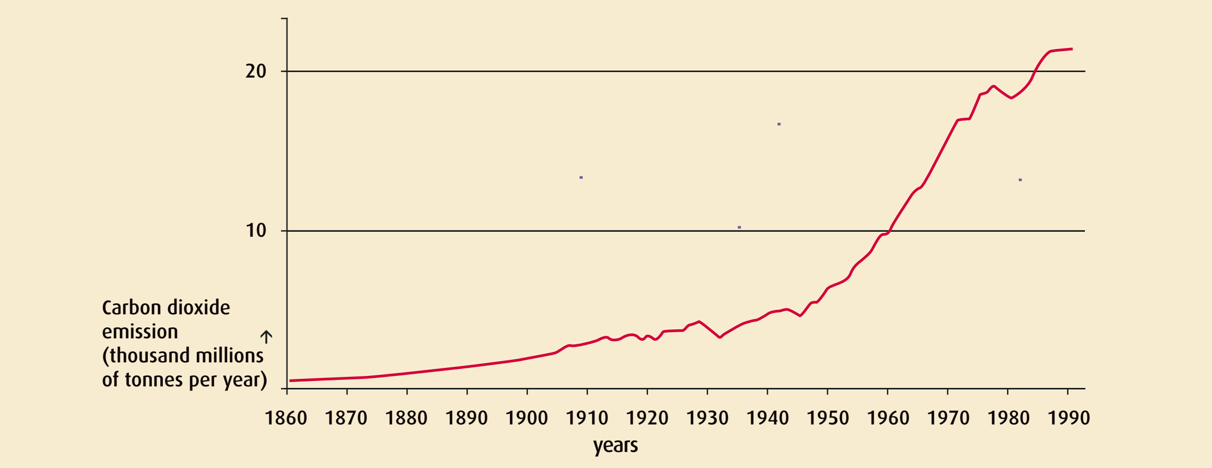
The Greenhouse Effect: Fact Or Fiction

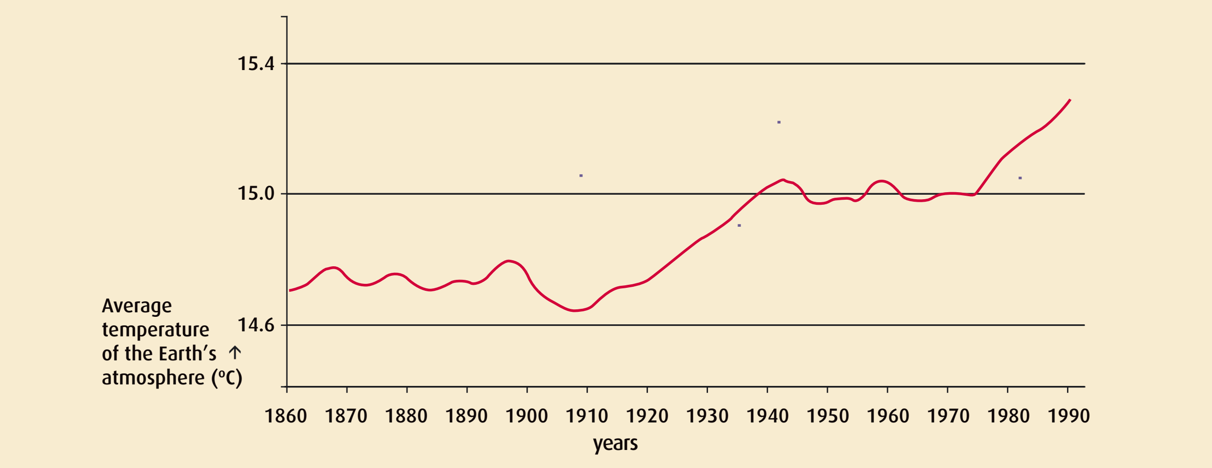
Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth. The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world.

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

As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term *greenhouse effect*. The greenhouse effect is said to have become more pronounced during the twentieth century.

It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century. A student named André becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth. In a library he comes across the following two graphs.





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

Question 3: GREENHOUSE:

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

Score	Response required	% Correct IRL	 OECD	Item Difficulty
Full	Refers to the increase of both (average) temperature and carbon dioxide emission **OR** refers (in general terms) to a positive relationship between temperature and carbon dioxide emission	59.5	53.9	Scale score 529 Level 3
Incorrect		31.1	32.4	
Missing	–	9.5	13.6	

Question 4: GREENHOUSE

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.

Score	Response required	% Correct IRL	 OECD	Item Difficulty
Full	Refers to one particular part of the graphs in which the curves are not both descending or both climbing and gives the corresponding explanation	23.0	22.4	Scale score 659 Level 5
Partial	Mentions a correct period, without any explanation **OR** only one particular year (not a period of time), with an acceptable explanation or refers to differences between the two curves/an irregularity in one of the graphs	27.8	24.1	Scale score 568 Level 4
Incorrect		30.5	27.6	
Missing	–	18.7	25.9	
Overall correct	(Partial credit responses weighted by 0.5)	36.9	34.5	

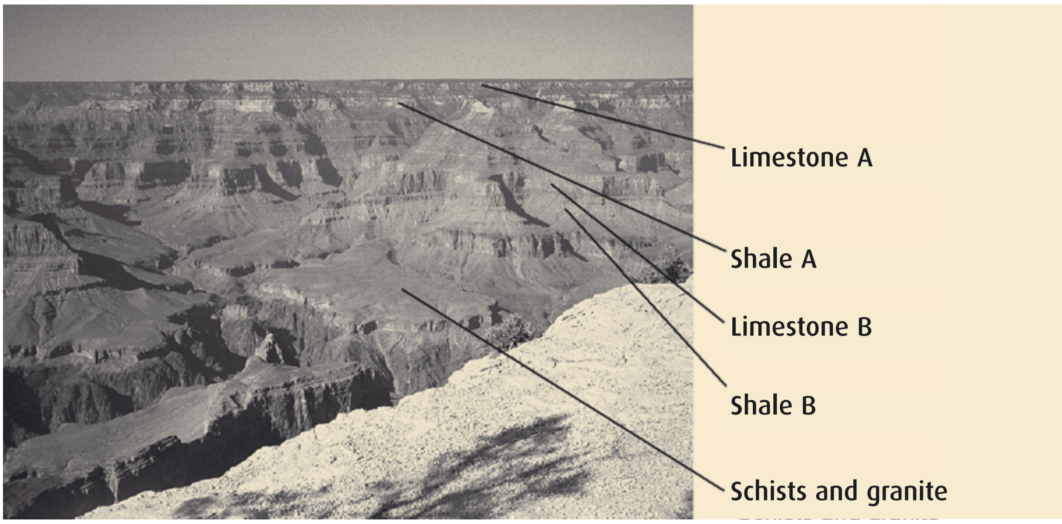
Question 5: GREENHOUSE

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.

Score	Response required	% Correct IRL	 OECD	Item Difficulty
Full credit	Gives a factor referring to the energy/radiation coming from the Sun **OR** to a natural component or a potential pollutant	19.1	18.9	Scale score 709 Level 6
Incorrect		50.4	45.6	
Missing	–	30.5	35.5	

The Grand Canyon

The Grand Canyon is located in a desert in the USA. It is a very large and deep canyon containing many layers of rock. Sometime in the past, movements in the Earth's crust lifted these layers up. The Grand Canyon is now 1.6 km deep in parts. The Colorado River runs through the bottom of the canyon. See the picture below of the Grand Canyon taken from its south rim. Several different layers of rock can be seen in the walls of the canyon.



Question 7: GRAND CANYON

About five million people visit the Grand Canyon national park every year. There is concern about the damage that is being caused to the park by so many visitors. Can the following questions be answered by scientific investigation? Circle "Yes" or "No" for each question.

Can this question be answered by scientific investigation?	Yes or No?
How much erosion is caused by use of the walking tracks?	Yes / No
Is the park area as beautiful as it was 100 years ago?	Yes / No

Score	% of responses		Item Difficulty
	IRL	OECD	
Correct - Yes, No	74.1	61.3	Scale score 485
Incorrect	25.2	37.3	Level 3
Missing	0.7	1.4	

Question 3: THE GRAND CANYON

The temperature in the Grand Canyon ranges from below 0°C to over 40°C. Although it is a desert area, cracks in the rocks sometimes contain water. How do these temperature changes and the water in rock cracks help to speed up the breakdown of rocks?

A Freezing water dissolves warm rocks.
B Water cements rocks together.
C Ice smoothes the surface of rocks.
D Freezing water expands in the rock cracks.

Score	% of responses IRL	OECD	Item Difficulty
Correct – D	87.2	67.6	Scale score 451 Level 2
Incorrect	11.4	29.0	
Missing	1.4	3.4	

Question 5: THE GRAND CANYON:

There are many fossils of marine animals, such as clams, fish and corals, in the Limestone A layer of the Grand Canyon. What happened millions of years ago that explains why such fossils are found there?

A In ancient times, people brought seafood to the area from the ocean.
B Oceans were once much rougher and sea life washed inland on giant waves.
C An ocean covered this area at that time and then receded later.
D Some sea animals once lived on land before migrating to the sea.

Score	% of responses IRL	OECD	Item Difficulty
Correct – C	70.2	75.8	Scale score 411 Level 2
Incorrect	26.4	20.6	
Missing	3.5	3.6	

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