Ready for Tomorrow's World?

The Competencies of Ireland's 15-year-olds in PISA 2006

Main Report

Eemer Eivers
Gerry Shiel
Rachel Cunningham

Educational Research Centre

Ready for Tomorrow’s World?

The Competencies of Ireland’s 15-year-olds in PISA 2006

Main Report

Ready for Tomorrow's World?

The Competencies of Ireland's 15-year-olds in PISA 2006

Main Report

Eemer Eivers
Gerry Shiel
Rachel Cunningham

Educational Research Centre
Dublin

Cataloguing-in-publication data

Eivers, Eemer

Ready for tomorrow's world? The competencies of Ireland's 15-year-olds in PISA 2006 - main report /
Eemer Eivers, Gerry Shiel, Rachel Cunningham.
Dublin: Educational Research Centre.

xx, 150 p., 30 cm.

ISBN: 978 0 900440 24 3

1. Programme for International Student Assessment (Project)
2. Science (Secondary) – Ireland
3. Mathematics (Secondary) – Ireland
4. Reading (Secondary) – Ireland
5. Academic Achievement
6. Educational Surveys – Ireland

2008

I Title. II Shiel, Gerry III Cunningham, Rachel.

371.262 – d/22

Cover designed by TotalPD

Printed in the Republic of Ireland by eprint Limited, Dublin

Table of Contents

List of Tables, Figures and Insets

Tables

Figures

Insets

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, 2003 and 2006 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 the second national publication on PISA 2006. The national summary report (Eivers, Shiel, and Cunningham, 2007) was published at the same time as the OECD's initial report on PISA 2006 (*PISA 2006: Science Competencies for Tomorrow's World*). It was designed for a general audience, and is available for download from *www.erc.ie/pisa*. The present report is a more in-depth analysis of the PISA 2006 data from an Irish perspective.

This report is divided into nine chapters. Chapter 1 provides some background to the study, describes what PISA measures, and explains how to interpret the analyses in the report. Chapter 2 provides an overview of achievement in earlier international studies, and factors associated with achievement. Chapter 3 describes Ireland’s performance on scientific literacy in PISA 2006 (overall, by subscales, by gender, and trends in scientific literacy). Chapter 4 details Irish students’ performance on the reading and mathematical literacy assessments, including trends in performance, while Chapter 5 relates the conceptualisation of, and achievement in, science in PISA to the Junior Certificate syllabus and Examination. Chapter 6 examines the links between various student characteristics and achievement, while Chapter 7 describes students’ attitudes to science and engagement in science-related activities. Chapter 8 examines the links between achievement and various school and classroom characteristics. Finally, Chapter 9 summarises the findings and discusses some of the more pertinent implications.

An appendix to the report contains a sample of science items used in PISA 2006. Also included are the percentage of correct responses (Ireland and OECD), an indication of the response required, a score on an item difficulty scale, and the proficiency level at which the item is located. Further sample items (including items relating to reading and mathematics) can be found on *www.erc.ie/pisa*.

Abbreviations used in this report are listed on page xiii. Statistical terms used are explained on page xiv.

Acknowledgements

We gratefully acknowledge the help of the PISA National Advisory Committee. As well as the authors of this report, the committee members were Doreen McMorris and Eamonn Murtagh (Department of Education and Science), Declan Kennedy and Tom Mullins (University College Cork), Elizabeth Oldham (Trinity College Dublin), Alison Graham (Sandford Park School, Dublin), Bill Lynch (National Council for Curriculum and Assessment), and Nick Sofroniou and Rachel Perkins (Educational Research Centre). Thanks are also due to Seán Close (St Patrick's College Dublin, PISA 2003 National Advisory Committee) and to Brian Murphy (University College Cork, PISA 2009 National Advisory Committee), who also commented on drafts of this report.

Thanks are due to staff at the Educational Research Centre, including Thomas Kellaghan, David Millar, John Coyle, Mary Rohan, and Hilary Walshe, to Jude Cosgrove, who was national project manager for PISA in Ireland until December 2005, and to Carly Cheevers, who was a research assistant on PISA until August 2007.

We thank Eddie McDonnell, who helped to match elements of PISA and the Junior Certificate science syllabus. We also acknowledge help received from a number of PISA consortium and of OECD Secretariat staff.

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

CBAS	Computer-based assessment of science
ERC	Educational Research Centre
ESCS	Economic, Social and Cultural Status (a measure developed for PISA)
IAEP II	Second International Assessment of Educational Progress
ICT	Information and Communication Technology
IRT	Item Response Theory
ISEI	International Socioeconomic Index
ISCO	International Standard Classification of Occupations
JCPS	Junior Certificate Performance Score
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
rJCSS	Revised Junior Certificate Science Syllabus
RME	Realistic Mathematics Education
SD	Standard Deviation
SE	Standard Error
SIMS	Second International Mathematics Study
TIMSS	Third International Mathematics and Science Study

Statistical Terms Used

Correlation

Correlation coefficients are measures of the relationship between two variables and can range from –1.00 to +1.00. A high correlation does not necessarily mean that one variable causes the other; the possible influence of other variables should always be considered. See Inset 1.2 on page 18 for help in interpreting correlations.

Plausible values

Plausible values are random numbers drawn from the distribution of scale scores that could be reasonably assigned to a student. As they contain random error variance components, they are not designed for reporting scores at the level of the individual, but are suitable for describing the performance of groups. See page 17 for more detail.

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. See page 17 for more detail.

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 significance of a 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 score on overall science). 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.

Executive Summary

PISA is an international survey of 15-year-old students' *literacy* in science, mathematics and reading that takes place every three years. The third cycle of PISA was implemented in 30 OECD member countries, including Ireland, and in 27 'partner' countries during 2006. In Ireland 4,585 students participated in the cognitive assessment, while, in total, almost 400,000 students across the world were assessed. Students completed a paper-and-pencil test and a student questionnaire. A school questionnaire was administered to school principals, and in Ireland, a questionnaire was administered to teachers of Junior Certificate science. The first international reports on PISA 2006 were released by the OECD in December, 2007 (OECD, 2007b, 2007c). A summary version of the Irish national report was published at the same time (Eivers, Shiel & Cunningham, 2007).

Summary of Main Findings

Students were administered tests in one major domain (science) and two minor domains (reading and mathematics).

Science Performance

Ireland's performance on scientific literacy was similar to performance in 2000 and 2003 – slightly, but significantly above the OECD average on the overall science scale. The Irish mean score was 508, compared to the OECD average of 500. Ireland's mean score is the 14th highest of the 30 OECD countries, and the 20th highest of all participating countries (true rank: between 10th and 16th among OECD countries). Unlike the average across OECD countries, where males significantly outperformed females, Irish males and females had almost identical mean science scores.

An examination of the spread of scores between the 5th and 95th percentiles (the range into which 90% of students' scores in a country fall) revealed that the Irish spread is very close to the OECD average spread. In contrast, although students in Northern Ireland obtained an almost identical mean science score to students in the Republic of Ireland, the gap between the two key markers was much larger in Northern Ireland, indicating a much larger spread of achievement. Slightly more students in Ireland reached the baseline science proficiency level of 2 than was average across OECD countries (85% versus 81%, respectively).

On the science competencies, Irish students' best performance was on *identifying scientific issues*, achieving the 8th highest mean score among OECD countries. The Irish means for *using scientific evidence* and *explaining phenomena scientifically* were also above the OECD mean, but the difference is significant only for *using scientific evidence*. Irish students showed consistency in performance across *knowledge of Earth and space systems*, *living systems* and *physical systems* and did not fall below the OECD average in any area. Females in Ireland demonstrated particular strength, relative to males, in *identifying scientific issues*, while males demonstrated particular strength in *Earth and space systems* and *physical systems*.

The strong correlation (r= .71) between Junior Certificate science grade and performance on PISA science indicates that students who performed well on one tended to perform well on the other. Most PISA science items were rated by an expert group as either very familiar or somewhat familiar to a Third year student studying the revised Junior Certificate science syllabus (rJCSS). This is in contrast to the last time PISA science items were rated (in PISA 2000), when the concepts underpinning roughly half of the items were rated as unfamiliar. There were only weak-to-moderate positive correlations between familiarity and the PISA science scores of students who had completed the rJCSS.

Attitudes to Science

Students in Ireland were well above the OECD average on *awareness of environmental issues* and similar to the OECD average for *general value of science* and *self-efficacy in science*. Fewer students in Ireland than on average across OECD countries indicated interest in studying topics in chemistry or physics, but more indicated interest in studying human and plant biology. Students in Ireland reported very low levels of engagement in out-of-school science-related activities such as watching TV programmes about science. Relative to female students, male students in Ireland and across OECD countries reported higher *awareness of environmental issues*, *self-efficacy in science* and *general value of science*. On the nationally-comparable indices, females reported stronger *instrumental motivation to learn science*, and stronger *future-orientated motivation to learn science* than males.

Reading Performance

As in PISA 2000 and 2003, the domain on which Irish students performed best was reading literacy. In all three assessments, Irish students obtained mean scores significantly above the OECD average. In 2006, Ireland's mean score on reading was 517, compared to the OECD mean of 492. In terms of country rankings, Ireland is the 5th highest of the 29 OECD countries[1] ('true rank': between 4th and 6th highest). Of all 56 countries for which reading data are available, only four (Korea, Finland, Hong Kong-China, and Canada) significantly outperformed Ireland.

The gap between Irish students' scores at the key percentile markers (5th and 95th) for reading is much smaller than the OECD average. Ireland also had proportionally fewer students falling below the baseline proficiency level of 2 than was average across OECD countries (12% versus 20%, respectively), and proportionally more students at the higher reading proficiency levels of 4 and 5. There are significant gender differences in performance on the reading assessment, in Ireland and in *all* countries that participated in PISA in 2006. In Ireland, females outperformed males by 34 points (534 versus 500), similar to the OECD average difference of 38 points. Only 8% of Irish females did not reach the baseline reading proficiency level, compared to 17% of Irish males.

[1] Reading literacy data for the United States were excluded due to an error in the test booklets, deemed to result in biased scores.

Mathematics Performance

As in PISA 2000 and 2003, Ireland's mean mathematics score was not significantly different from the OECD average. Ireland's score in 2006 was 502, compared to an OECD average of 498. In terms of country rankings in PISA 2006, Ireland's mean score is the 16th highest of the 30 OECD countries ('true rank': between 12th and 17th highest) and the 22nd highest of all 57 participating countries.

Ireland and Finland have the narrowest spread amongst OECD countries 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. Unlike for reading and science, Ireland had proportionally fewer students at the highest proficiency levels than the OECD average (approximately 10% of students versus an OECD average of 13%). On a more positive note, a smaller percentage of students in Ireland fell below the baseline proficiency level of 2 for mathematics (16%, versus an OECD average of 21%). As in most countries, males in Ireland outperformed females, and the magnitude of the gap was very similar to the 11-point gap found across all OECD countries. Less than 1% of females in Ireland, compared to 2.4% of males, achieved the highest mathematics proficiency level of 6.

Factors Related to Achievement

Many student- and school-level factors were significantly related to achievement. In particular, student socioeconomic status, as defined by the PISA measure of ESCS (economic, social and cultural status), was associated with achievement on each of the PISA domains of science, reading and mathematics. While the link between ESCS and achievement is slightly weaker in Ireland than the OECD average, it is significantly linked to achievement at the level of the individual student and at the level of the school. Factors such as school sector, size, and gender composition were related to achievement, but also to ESCS.

There was not a significant difference in the mean scores obtained by 'native' Irish students and the 6% in Ireland not classified as native. Higher achievement was associated with smaller family size, higher parental educational attainment, and speaking either English or Gaeilge at home, rather than 'other' languages.

Many home environment variables were related to achievement (e.g., number of books in the home, availability of educational resources, and the extent of student-parent interaction). However, while change was apparent since PISA 2000 on some characteristics (e.g., parental educational attainment had increased, almost all 'affluence indicators' had increased), other characteristics of the home environment remained unchanged (e.g., number of books in the home). In 2006, Ireland was above the OECD average on most affluence indicators, but slightly below average on indices of educational resources and cultural possessions in the home.

Highest scores in Ireland were obtained by Transition year students (but this could be attributable to their atypical socioeconomic composition). Almost half of students had been absent from school for at least one day in the fortnight preceding the assessment. These students obtained lower mean scores than students who had attended all days in the same period. A large group (43%) of students reported being bullied (e.g., name-calling or physical abuse) in the school term in which PISA took place. Those who had not experienced bullying in any form obtained higher mean scores than those who had. As in PISA 2000 and 2003, students who had not taken Junior Certificate science did not differ significantly in average science achievement from students who had taken the subject at Ordinary Level.

Examining the variation in student science performance that can be attributed to differences *between* schools, the percentage in Ireland is about half the OECD average (17% versus 32%, respectively). This means that compared to the average across OECD countries, Irish schools performed at a reasonably similar level to each other, with greater variation found *within* schools. Compared to the norm for OECD countries, Irish schools were more likely to use familial links and endorsement of a particular philosophy as student admission criteria, and more likely to place students in ability groups. The student:computer ratio was considerably poorer in Ireland than the OECD average, but the student:teacher ratio (which included support as well as classroom teachers) was very close to the OECD average.

Many of the attitudinal scales showed strong positive correlations with overall science achievement (and with each other). In contrast, an increase in *optimism regarding environmental issues* was associated with a drop in achievement, suggesting that lower-achieving students may be overly optimistic about the extent to which key environmental problems will be resolved over time.

Implications

Overall Performance in Science

The finding that Ireland's performance on science has not changed since 2000 could be considered surprising, given that the rJCSS has created a closer alignment between PISA science and science as experienced by Irish students. However, performance on the science assessment seems less linked with familiarity than is the case for the reading and mathematics assessments. Furthermore, the rJCSS may not be in place long enough to affect performance in PISA (2006 was the first year it was examined). The implementation of the syllabus over the coming years should be monitored, in particular, to see how two elements – the Science-Technology-Society (STS) approach and Coursework – are implemented in practice.

Ordinary Level Science and PISA Science

The finding of no difference in achievement between Ordinary Level students and non-science students suggests a need to examine in greater detail the characteristics of Ordinary level students, not only in relation to their performance on specific aspects of PISA science (i.e., a detailed description of their knowledge and competencies), but also in terms of their attitudes towards and engagement in science.

Engagement in Science

The low engagement of students in Ireland in science-related activities such as watching a TV programme about science or reading a magazine or newspaper article is a cause for concern. Given the importance of applying scientific concepts to real-life situations, there may be value in examining ways in which schools and parents can support students to engage more in science-related activities.

Low- and High-Achieving Students

The PISA data suggest that while Ireland has had a measure of success in dealing with the needs of lower achievers, we have been less successful in meeting the needs of the higher-achieving student, particularly where mathematics is concerned. The relative lack of high-achieving mathematics students may be related to uptake of Junior Certificate mathematics, but other factors may warrant exploration. It remains to be seen if new developments such as Project Maths will be diverse enough in content and focus to raise the achievement of high performers as well as catering to the needs of students at other performance levels. Those involved in the teaching of English and science might also reflect on measures to stimulate higher achievement among more academically able students.

The Effects of the Home

Ireland was above the OECD average on almost all affluence indicators, but ranked 21st of the 30 OECD countries on the index of availability of educational resources in the home and 26th on an index of cultural possessions in the home. Examining changes since PISA 2000, there has been a noticeable increase in 'affluence' variables, but no appreciable change in educational or cultural resources in Irish homes. It would seem that greater efforts need to be made to show parents simple ways to support their child's academic development.

School Effects

PISA data suggest that the advantage to attending certain types of schools often derives from the characteristics that students bring to the school (in particular, their socioeconomic status), rather than to 'added-value' from attending a particular school. Schools can 'add-value', but how they do so is complex, and effects can vary depending on the combination of school characteristics and individual student need.

Changing Performance at a National Level

There has been little substantive difference in how Irish students have performed over the three PISA cycles (2000 – 2006). This should not give the impression that change cannot be effected at a national level. Countries such as Korea and Poland have made significant improvements on the PISA reading literacy test, which some (e.g., OECD 2007b) have attributed to changes to curriculum or to the structure of their educational system. Other countries, such as France and Northern Ireland, have seen a decline in performance on the PISA mathematics test.

Chapter 1
PISA 2006: Overview and Implementation

The Programme for International Student Assessment (PISA), which is conducted under the auspices of the Organisation for Economic Co-Operation and Development (OECD), seeks to measure how well young adults (at the age of 15 years) approaching the end of compulsory schooling are prepared to meet the challenges of today's knowledge societies (OECD, 2004b). Since 2000, students' knowledge and skills have been assessed at three-year intervals in the domains of reading, mathematics and science[1]. The focus is not on students' knowledge of curriculum content, but rather on how well students can apply what they have learned to real world situations. The term 'literacy' is used to denote this broader, real-life, conceptualisation of skills and knowledge. Inset 1.1 summarises some of the main features of PISA.

Inset 1.1: Key Features of PISA

- PISA is an international standardised assessment of the literacy achievements of 15-year-olds. It takes place every three years.
- In 2006, almost 400,000 students took part. The 57 participating countries (including all 30 OECD member countries) represent one-third of the world's population.
- PISA assesses students' scientific, reading, and mathematical literacies.
- The emphasis is on the *use* of knowledge and skills to meet real-life challenges, on mastering processes, and on understanding concepts.
- Students are assessed using paper-and-pencil tests, containing both multiple-choice and open-ended questions. In PISA 2006, a small number of countries also administered a computer-based assessment of science, while in 2009, some countries will assess the reading of electronic texts.
- Students complete a questionnaire to provide some background information about themselves and their home. Principals complete a school questionnaire.
- PISA produces a profile of student skills and knowledge and contextual indicators relating results to student and school characteristics.
- Data collected over time provide trend indicators that show changes in performance and other outcomes over time.

Adapted from OECD (2007b), Box 1.1, p. 19

[1] Reports on the international results from 2000 and 2003 (OECD, 2001; OECD, 2004b) can be found at *www.pisa.oecd.org*, while national reports for Ireland (Shiel, Cosgrove, Sofroniou & Kelly, 2001; Cosgrove, Shiel, Sofroniou, Zastrutski & Shortt, 2005) can be found at *www.erc.ie/pisa*.

In each year in which an assessment was carried out, reading, mathematics or scientific literacy was designated as the major domain. Having major and minor domains means that the former can be looked at in detail, while performance on the minor domains can be described in broader terms, with observation of changes over time within each domain. Reading literacy was the major domain in PISA 2000, and will again be the main domain in 2009. In 2003, mathematics was the major domain, and in 2006 it was scientific literacy. Of the 179 test items used in 2006, 103 related to the assessment of scientific literacy (Table 1.1).

Table 1.1: Content across PISA cycles (2000-2009)

Year	Major Domain	No. of items	Minor Domains	No. of items	Other themes explored
2000	Reading	141	Mathematics	32	Equity and literacy; reading attitudes and habits; students' self-regulated learning
			Science	35	
2003	Mathematics	85	Science	35	Variables associated with performance in mathematics; attitudes to mathematics; educational pathways
			Reading	28	
			Problem solving	19	
2006	Science	103	Reading	28	Information and communication technologies; attitudes to science
			Mathematics	48	
2009	Reading	–	Mathematics	–	Electronic reading; reading supports in school environments
			Science	–	

Fifty-seven countries (all 30 OECD member countries, plus 27 'partner' countries) participated in the 2006 assessment (Table 1.2). This represented a significant expansion on the number of countries that participated in 2000 (32 countries, plus 11 additional countries in 2002) and in 2003 (41 countries). In 2006, almost 400,000 15-year-olds, enrolled in school- or work-based educational programmes, completed a paper-and-pencil test and a student questionnaire. A school questionnaire was administered to school principals, and in Ireland, a questionnaire was administered to teachers of Junior Certificate science. In three countries (not including Ireland), students participated in an additional computer-based assessment of science.

Table 1.2: Countries participating in PISA 2006

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

Content of the Assessment

A central focus of PISA is the assessment of young people's ability to use their knowledge and skills to meet real-life challenges. This emphasis is reflected in the structure of tests. Rather than presenting a large number of independent test items (questions), 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. This design allows items to be framed in more realistic and complex contexts, and makes effective use of limited test time.

PISA includes a variety of item types. While some questions are multiple-choice (a student selects one of four pre-defined response options), others require students to write a response. These *constructed responses* can be divided into *closed-constructed responses* (the written response is typically very short, and there is one clear, correct answer) and *open-constructed responses* (student responses are required to be more detailed, there is a range of possible answers, and, for some, students may be awarded full or partial credit). Some examples of PISA test items and units can be found in Appendix A, while a more extensive range is available at *www.erc.ie/pisa*.

Each domain (science, reading and mathematics) is underpinned by a framework that both defines the domain and guides item development. The frameworks for the domains, though quite different, share some structural characteristics. Thus, each domain is defined in terms of the situations or contexts in which the assessment is grounded, the processes that need to be performed, and the type of content or knowledge that students need. In this section, we summarise some of the main elements of the frameworks. A more detailed description is available in the PISA 2006 framework *'Assessing Scientific, Reading and Mathematical Literacy'* (OECD, 2006).

Framework for Scientific Literacy

The 2006 PISA framework defines scientific literacy as:

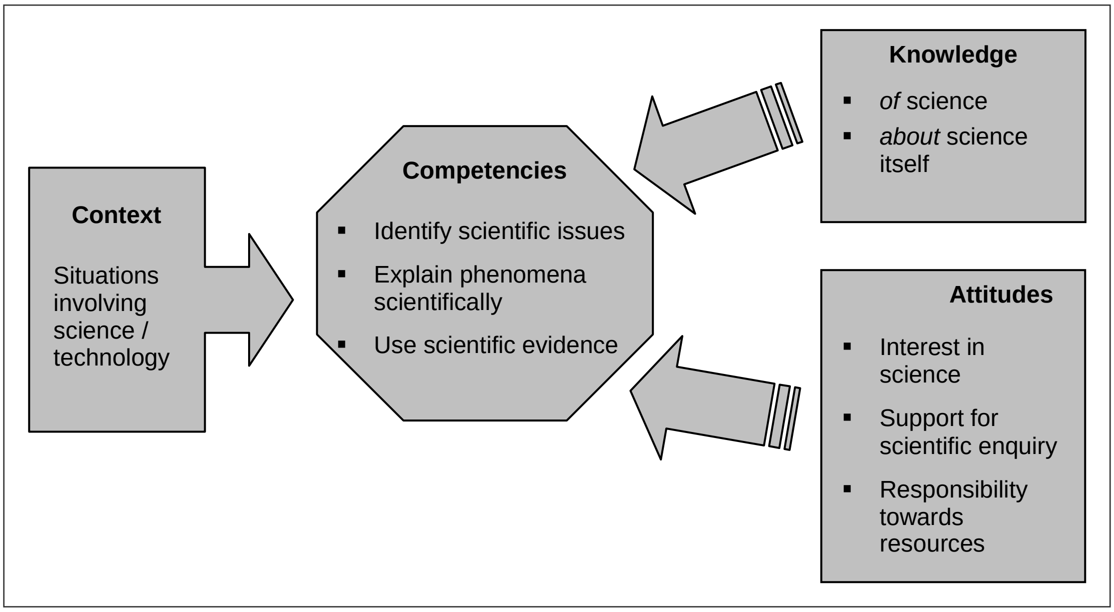
> an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen. (OECD, 2006, p. 12).

Four interrelated dimensions are central to this definition (see Figure 1.1):

- **Context:** Recognising situations that involve science and technology.
- **Knowledge:** Using scientific knowledge (of the natural world and about science itself) to understand the natural world.
- **Competencies:** Displaying the ability to identify scientific issues, explain phenomena scientifically, and draw evidence-based conclusions.

- **Attitudes:** Showing interest in science and scientific enquiry, and belief in the need to act responsibly toward, for example, natural resources and environments.

Figure 1.1: Framework for scientific literacy



Adapted from Figure 1.1, OECD 2006

Context

The PISA 2006 framework for scientific literacy focuses on science within 'real-life' contexts rather than concentrating on school science programmes only. An important aspect of scientific literacy is that students should be able to engage with science in a variety of settings or contexts. Therefore, assessment items were grounded in a variety of contexts, or situations, that are believed to be relevant to students' lives and interests. The overall assessment is designed to assess students' scientific literacy in a mixture of personal (self, family, and peer groups), social (community), and global contexts.

Knowledge

Scientific literacy refers to both *knowledge of science* and *knowledge about science*. Knowledge *of* science refers to knowledge of the natural world across the major fields of physics, chemistry, biological science, Earth and space science, and technology. Given the huge range of potential topics, item topics were selected from each of the major fields of science using the following criteria: relevance to real-life situations; representative of important scientific concepts and thus having enduring utility; appropriateness to the developmental level of 15-year-olds.

Knowledge *about* science can be divided into *knowledge about scientific enquiry* and *knowledge about scientific explanations*. Scientific enquiry refers to knowledge of the means and methods of science - how scientists get data. Scientific explanations are the results of scientific enquiry – how the data are used.

Competencies

The concept of competencies is central to the PISA framework. PISA describes scientific literacy in terms of three scientific competencies, viewed as important skills for scientific investigation and analysis as they require logic, reasoning, and critical analysis.

- **Identifying scientific issues**: Recognising issues that can be investigated scientifically, identifying keywords to search for scientific information and recognising the key features of a scientific investigation. Students demonstrating this competency need knowledge *of* science and knowledge *about* science.
- **Explaining phenomena scientifically:** Applying knowledge *of* science in a given situation, describing or interpreting phenomena scientifically and predicting changes, and identifying appropriate descriptions, explanations and predictions.
- **Using scientific evidence:** Interpreting scientific evidence, drawing conclusions, identifying the assumptions, evidence and reasoning behind conclusions, and reflecting on the societal implications of science and technological developments. Students demonstrating this competency must make sense of scientific findings and be able to draw conclusions from them.

Attitudes

PISA 2006 views attitude and actions as part of scientific literacy. Attitudes were evaluated in four areas: *interest in science*, *support for scientific enquiry, self-belief as science learners* and *responsibility towards resources and environments*. A student questionnaire and contextualised test items were used to gather data about students' attitudes in these areas. Including attitudinal items in both settings allowed for a more detailed examination of the relationship between attitudes and performance on the assessment. It was possible to see if students' attitudes differed when assessed in and out of context (in the test booklet, surrounded by relevant test items, or in the questionnaire).

PISA 2006 Science Test Characteristics

The science assessment was based on the main elements of the PISA science framework, as outlined above. Thus, each item was designed to assess one of the scientific competencies within a personal (17.5% of items), social (55.3%), or global (27.2%) context. Furthermore, each item was categorised as requiring students to use either their *knowledge of science* or their *knowledge about science*. Within each test unit, different items typically assessed different competencies and knowledge categories (i.e., *knowledge of* or *about science*). Almost half of science items assessed the competency of *explaining phenomena scientifically*, while 30% related to *using scientific evidence*, and 23% to *identifying scientific issues* (Table 1.3).

Table 1.3: Distribution of PISA 2006 science items by competency

Competency	N	%
Identifying scientific issues	23	23.3
Explaining phenomena scientifically	49	47.6
Using scientific evidence	31	30.1
Total	103	100.0

Just over half (56%) of PISA science items were categorised as requiring students to demonstrate *knowledge of science*, with 44% assessing *knowledge about science* (Table 1.4). Within *knowledge of science*, *living systems* and *physical systems* had the greatest representation (21% and 17% of all items, respectively). Almost 11% of items examined *knowledge of Earth and space systems*, while 8% assessed *technology systems*. Items assessing *knowledge about science* were relatively evenly divided between *scientific enquiry* (24% of all items) and *scientific explanations* (20%).

Table 1.4: Distribution of PISA 2006 science items by scientific knowledge

Main categories	Sub-categories	N	%
Knowledge of Science	Earth and Space systems	11	10.7
	Living systems	22	21.4
	Physical systems	17	16.5
	Technology systems	8	7.8
	Subtotal	58	56.3
Knowledge about Science	Scientific enquiry	24	23.3
	Scientific explanations	21	20.4
	Subtotal	45	43.7
	Total	103	100.0

PISA 2006 science results are reported on three subscales – based on the three competencies – as well as on an overall science scale. Performance also is reported on subscales based on *knowledge about science* and the *knowledge of science* content areas of *living systems, physical systems,* and *Earth and space systems*. Performance is not reported for *knowledge of technology systems* as the number of items assessing the content area was insufficient to develop a separate scale.

Framework for Mathematical Literacy

The PISA conceptualisation of mathematical literacy is based on realistic mathematics education (RME) (e.g., Freudenthal, 1973), in which solving mathematical problems in real-world settings is heavily emphasised. The idea of 'mathematising' is central to RME. Mathematisation involves taking a problem in a real-world context, organising it according to mathematical concepts and gradually 'trimming away the reality'. Assumptions are made about which features of the problem are important, thus allowing the mathematical problem to be solved. The final step is to make sense of the mathematical solution in terms of the real situation. Mathematics was the main PISA domain in 2003; the definition guiding the framework in 2006 was that developed for the 2003 assessment. Thus, 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).

Mathematical literacy is classified on three main dimensions: situations and contexts; content; and competencies.

Situations and Contexts

The ability to use mathematics in a variety of situations is considered an important part of mathematics, as the type of mathematics used can depend on the situation in which the problem is presented. Situations are 'the part of the student's world in which the tasks are placed' (OECD, 2006, p. 81), with the closest situation being the student's personal life, followed by educational/occupational situations. Public situations and scientific situations are described as placed furthest from the student's world. An item's context is its specific setting within a situation. For example, an item dealing with bank interest rates could be categorised as representing a public situation and a context related to money or interest rates.

Content Areas

PISA mathematics content is defined in terms of four 'overarching ideas':

- **Space & Shape:** recognising and understanding geometric concepts and patterns, and identifying such patterns in abstract and real-world representations.
- **Change & Relationships:** recognising relationships between variables and thinking in terms of and about relationships in a variety of forms including symbolic, algebraic, graphical, tabular, and geometric.
- **Quantity:** understanding relative size, recognising numerical patterns and using numbers to represent quantities and quantifiable attributes of real-world objects.
- **Uncertainty:** solving problems relating to data and chance.

Competencies/Processes

PISA identifies eight types of cognitive process involved in mathematisation – reasoning; argumentation; communication; modelling; problem-posing and -solving; representation; using symbolic, formal and technical language and operations; and use of aids and tools. A mathematical task may involve one or more of these processes at various levels of complexity. In PISA, these processes are represented at different levels of complexity in three broad competency clusters:

- **Reproduction:** Students reproduce practised knowledge (e.g., repeating facts, performing routine procedures, applying algorithms, manipulating formulae and carrying out computations).
- **Connections:** Students solve problems in less routine situations – 'integrating, connecting and modest extension of practised material' (OECD, 2006, p. 102).
- **Reflection:** Students use the competencies from *reproduction* and *connections*, but also demonstrate advanced reasoning, and the ability to abstract and generalise in new contexts.

PISA 2006 Mathematics Test Characteristics

The mathematics assessment is based on the main elements of the mathematical literacy framework. Each of the four overarching ideas is represented in close to one quarter of items (Table 1.5). Half of the test items assess the *connections* competency cluster, while the remainder are almost equally divided between *reproduction* and *reflection*. Item situations (or contexts) are somewhat unevenly divided. Close to 40% of items have a public context, while 25% have a scientific context. Personal contexts frame 19% of items, and 15% have an educational setting. The small minority remaining relate to occupational and intra-mathematical contexts. PISA 2003 reported data for a combined mathematical literacy scale and for four subscales (based on the four overarching ideas). Due to the much smaller mathematics item pool in 2006, only results for a combined mathematics scale are produced, although comparisons are made with performance on the 2003 assessment.

Table 1.5: Distribution of PISA 2006 mathematics items by context, competency and overarching idea

Situation /context	N	%	Competency	N	%	Overarching Idea	N	%
Public	18	37.5	Connections	24	50.0	Quantity	13	27.1
Scientific	12	25.0	Reflection	13	27.1	Change & relationships	13	27.1
Personal	9	18.8	Reproduction	11	22.9	Uncertainty	11	22.9
Educational	7	14.6				Space & shape	11	22.9
Occupational	1	2.1						
Intra-maths	1	2.1						
Total	48	100	Total	48	100	Total	48	100

Framework for Reading Literacy

PISA reading literacy is much broader than the ability to decode a piece of text (literal comprehension), and encompasses students' ability to understand and to *use* what they read. Reading was the main PISA domain in 2000, and the definition used in 2006 was that developed for 2000:

> 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)

Three dimensions are considered as at the core of this view of reading: the content and structure of texts; the processes that need to the performed; and the situations in which knowledge and skills are drawn on or applied.

Text Content/Structure

Texts are categorised as either continuous or non-continuous. Continuous texts are typically composed of sentences that are, in turn, organized into paragraphs. The framework defines five broad types, based on text content and the author's aim:

- **Narrative***:* For example, stories, reports and news articles, usually providing answers to 'when' or 'in what sequence' questions.
- **Expository**: For example, definitions, explications, summaries and essays. Expository texts answer 'how' questions.

- **Descriptive***:* Such texts provide descriptions of persons, places or objects. They typically provide an answer to 'what' questions.
- **Argumentative***:* Such texts deal with relationship between concepts, or other propositions, often answering 'why' questions.
- **Injunctive***:* For example, providing instructions on what to do, or procedures, rules, regulations and statures specifying certain behaviours.

Non-continuous texts (or documents) are organised in a different manner from continuous text, and require a different reading approach. In PISA 2006, non-continuous texts included charts and graphs, tables, diagrams, maps, forms, and advertisements.

Reading Processes

Reading items are also categorised by the processes underlying reading literacy. Students are expected to engage in the following processes:

- **Retrieve:** Students must find a particular piece of (explicitly stated) information from within the text.
- **Interpret:** Students need to have a broad general understanding of the text, and may need to develop an interpretation.
- **Reflect and evaluate:** Students must use information from within the text as well as information from outside the text.

Each of these processes is required to understand texts, and it is expected that all readers should be able to exhibit some level of ability in each of the processes.

Reading Situations

Texts are also categorised by the situation of the text (where they are intended for use). Four main situations were described:

- **Private/personal**: Reading to satisfy one's own interests.
- **Public:** Reading for participation in the activities of the wider society.
- **Occupational:** Reading of the type found in occupational settings.
- **Educational**: Reading to acquire information as part of a broader learning task.

PISA 2006 Reading Test Characteristics

The items included in the PISA 2006 reading test are relatively evenly distributed across the four main types of situation, although slightly more reflect educational situations than other types of situations (Table 1.6). Approximately two-thirds of items are based on continuous texts, with the remainder based on non-continuous texts. Half of items assess students' skills at *interpreting texts*, 25% assess the *retrieve* process, and 25% require students to *reflect on and evaluate* a text.

Table 1.6: Distribution of 2006 reading items by structure, situation and process

Text Structure	N	%	Situation	N	%	Process	N	%
Continuous	18	64.3	Personal	6	21.4	Interpret	14	50.0
Non-continuous	10	35.7	Public	7	25.0	Reflect/ Evaluate	7	25.0
			Occupational	7	25.0	Retrieve	7	25.0
			Educational	8	28.6			
Total	28	100.0	Total	28	100.0	Total	28	100.0

PISA 2000 reported data for a combined reading literacy scale and for five subscales (two based on text type and three based on process). Due to the much smaller reading item pool in 2006, performance on reading literacy is reported with reference to the combined reading literacy scale only. Comparisons are made with performance on the 2000 and 2003 assessment.

The PISA Context Questionnaires

In addition to the assessments of scientific, reading, and mathematics literacy, PISA gathers 'contextual' information from questionnaires. This information aids in the interpretation of results, as it allows links to be made between test performance and school and student characteristics. All participating countries were required to administer questionnaires to students and to their school principals. These questionnaires consisted of a core set of questions, to which countries could add a small number of questions of national interest. In addition, 39 countries (including Ireland) chose to administer an optional questionnaire module on information and communication technology (ICT) literacy as part of the student questionnaire.

Sixteen countries (not including Ireland) administered a questionnaire to parents of participating students. PISA 2006 did not include a teacher questionnaire. However, in Ireland, since the assessment coincided with the first examination of the revised Junior Certificate science syllabus (rJCSS), a questionnaire was developed specifically for those teaching Junior Certificate science in participating schools. 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). The contents of all questionnaires administered in Ireland are summarised below, and all (with the exception of the science teacher questionnaire which is available at *www.erc.ie/pisa*) are available in full at *www.pisa.oecd.org*.

As well as reporting responses to various questions, PISA reports on many 'indices', which are summary measures of responses to a set of related questions. For example, a set of questions examining students' perceptions of their ability to solve a series of science problems might be combined to produce an index of self-efficacy in science. Each index is constructed so that it has an OECD mean of zero and a standard deviation of one. Thus, approximately two-thirds of students in OECD countries will score between −1 and +1 on the index. A negative score (e.g., −0.5) does not necessarily mean a negative response from the student. For example, an important PISA index is the index of economic, social and cultural status (ESCS), derived from data relating to parental employment and education, and cultural, educational and other resources in the home. A negative score on this index might simply reflect a student whose parents had not completed post-primary education.

The overall conceptual model for PISA – which guides the development of both questionnaire and achievement instruments – draws on earlier models of educational systems such as those proposed by Travers and Westbury (1989), Carroll (1963), Creemers (1994), and Schmidt and Cogan (1996). Four levels (system, school, classroom and student) are defined (Figure 1.2). These relate not only to four potential levels at which data might be collected, but also to the structure of national education systems. Also mirroring many earlier models is the division of variables at each level into antecedents, processes, and outcomes.

Figure 1.2: Conceptual framework for PISA 2006

	Antecedents	Processes	Outcomes
System	**Country characteristics**	**National education policies & organisation**	**System level**
Examples	*Gross Domestic Product, cultural homogeneity*	*Funding, teacher qualifications, school entry age, retention rates, extent of streaming, grinds*	*National standards in reading, mathematics, science, equity related outcomes*
School	**School characteristics**	**Policies and conditions**	**School level**
Examples	*Parent characteristics, location, funding, size, management structure*	*Policies on assessment, admission, timetabling, teacher support* *Equipment & staffing, academic orientation, school climate*	*Achievement and attitudes within the school,* *School context effects on students*
Classroom	**Classroom characteristics**	**Learning environment**	**Class level**
Examples	*Teacher background characteristics* *Student, class or course characteristics*	*Processes (e.g., orderliness, teacher-student relations, teacher supportiveness)* *Practices (homework, differentiation, lesson structures)*	*Average classroom performance*
Student	**Student characteristics**	**Student learning process**	**Student level**
Examples	*Age, gender & peer group* *Family characteristics (SES, parental educational attainment & involvement, home resources, ethnicity, language)*	*Attitudes to & engagement with school life (attendance, use of resources, homework, additional support programmes)*	*Attainment in science, mathematics & reading* *Attitudes to and confidence with science*

Adapted from OECD (2004a)

School-level antecedents include factors such as school size and management structure, while student antecedents include gender and family background. Examples of processes range from national education policies (system-level) to student engagement in homework, while outcomes range from how a student does on a reading test to national reading standards. Most such models contain assumptions that antecedents influence processes, which in turn produce outcomes, and that higher level variables affect lower level ones (e.g., system factors affect school factors). Some also assume that this direction can be reversed (e.g., an outcome variable such as student achievement might influence a process variable such as lesson structures). However, due to the complexity of relationships between variables and levels, the PISA general conceptual model summarised in Figure 1.2 does not explicitly state causal relationships.

While all collected data can be mapped back onto the PISA conceptual model, not all cells in the framework were examined. For example, system-level antecedents are not part of PISA data. Of those cells for which data were collected, the one of most interest is probably student-level outcomes (data collected include the cognitive assessment and parts of the student questionnaire). Other parts of the student questionnaire fall under student characteristics and learning processes. In Ireland, through a combination of the school and science teacher questionnaires, PISA also collected data at the school and classroom levels. The remainder of this section outlines the contents of the questionnaires administered.

Student Questionnaire

Students who participated in the cognitive assessment were also asked to complete a questionnaire. Core topics – asked in all countries – included questions on background (e.g., gender, family structure, parental employment, home educational resources); attitudes toward science, environmental issues and science-related careers; experience of studying science in school; and amount of time spent studying the three domain subjects (test language, mathematics and science). Students in 39 countries, including Ireland, completed an optional module which enquired about familiarity with and usage of ICT. Irish students also answered a number of policy-relevant questions developed by the national centre (the Educational Research Centre). These included involvement in family activities; number of siblings; engagement in work; experience of bullying; intentions of remaining in school until Leaving Certificate; and, absenteeism. Students were also asked if Junior Certificate science was compulsory in their school, and those who had not studied science were asked for their reasons for not doing so.

Junior Certificate Science Teacher Questionnaire

In Ireland, a questionnaire was administered to teachers of Junior Certificate science in participating schools. Topics included teacher background characteristics, teachers' views on the rJCSS, lesson planning and classroom activities, and linkages between the PISA science framework and science teaching in Irish schools. Some of the main data from the science teacher questionnaire have been described in the report *Implementing the Revised Junior Certificate Syllabus: What teachers said* (Eivers et al., 2006). The report is available from *www.erc.ie/pisa.*

School Questionnaire

The principals of all participating schools were asked to complete a school questionnaire. Core topics included the following: school structure; staffing; resources; admission procedures; accountability; decision-making; school's engagement with science; student uptake of science; and careers advice service. In Ireland, principals were asked about the following additional topics: availability and uptake of Transition year; Third year students' awareness about science courses/careers; availability of 'taster' courses for Junior Certificate science; uptake of science at Junior Certificate and school policies to promote uptake of science at Leaving Certificate.

Implementation of PISA 2006 in Ireland

This section describes the implementation of PISA 2006 in Ireland, including the 2005 field trial and the main study in 2006. The assessment was implemented by the Educational Research Centre (ERC) on behalf of the Department of Education and Science (DES).

Development of Test Materials and Questionnaire Items

Participating countries were invited to submit science test units to the international consortium for possible inclusion in the field trial. New material was assessed in terms of 'fit' with the PISA science framework and appropriateness for the target population. A subset of units was included in a field trial (described below) in which only science was assessed. After the field trial, analyses of relative difficulty, psychometric properties, and differential item functioning (e.g., unexpected gender differences relative to student ability) were conducted. Based on the outcomes of these analyses, a final subset of items and units was selected for inclusion in the main study. The items used in school and student questionnaires were developed in a similar manner.

Field Trial 2005

A field trial was conducted in 2005 to familiarise participating countries with the implementation of PISA, to determine the appropriateness of the new science items, and to examine the effectiveness of operational procedures. In Ireland, 1,200 students in 41 schools in Dublin, Cork and Galway were assessed in March 2005. The assessment was administered in schools by specially-trained administrators, drawn from the ranks of retired school inspectors and principals. Some PISA items must be scored by trained coders. For the 2005 field trial, all coders used were third-level students with specialisations in science and/or psychology.

Thirteen countries, including Ireland, participated in the optional computer-based assessment of science (CBAS). The purpose of CBAS was to examine the feasibility of using computers to administer assessments and to observe the extent, if any, to which CBAS added to a paper-based assessment. CBAS was conducted alongside the general field trial on a subset of 400 students in 30 Dublin schools. Five test administrators were trained to conduct the assessment.

In general, the field trial was implemented as planned in Ireland. However, while the CBAS element proved popular with school staff and students, a number of implementation difficulties were identified (in Ireland and in most of the countries that took part in CBAS). Firstly, the administration required high technical competence on the part of test administrators, making it difficult to recruit appropriate individuals. Secondly, the transport of laptops (used to administer the test) posed logistic and security problems, and the administration proved extremely costly, a problem which was not counterbalanced by a clear 'added-value' from CBAS. For these and other reasons, Ireland was not one of the three countries that chose to participate in CBAS as part of the main study in 2006. Details on the implementation and review of CBAS in Ireland can be found by accessing *http://www.erc.ie.*

Main Study 2006

The main study for PISA 2006 took place in Ireland between mid-March and early April 2006. This section outlines the PISA target population in Ireland and describes exclusions. The sample design and test administration are also described.

Target Population

PISA is targeted at 15-year-old students enrolled in grade 7 (equivalent to First year in a post-primary school) or higher. For the purposes of the 2006 study, 15-year-olds were defined as those born between January 1st 1990 and December 31st 1990. According to the Central Statistics Office website, 53,044 births were registered in Ireland in 1990. However, due to immigration trends, this is likely to under-represent significantly the number residing in Ireland in 2006 who were born in 1990. Collating data from the DES, non-aided schools, and special needs schools, it can be determined that 58,198 15-year-olds were enrolled in such facilities. Allowing for an estimated enrolment rate in school-based programmes (i.e., excluding Youthreach centres and Senior Traveller programmes) of 99.2%, this suggests a 'national population' of 58,667. However, the PISA target population is restricted to those in grade 7 or higher in a recognised school, meaning that the 662 (estimated) 15-year-olds enrolled in special needs schools had to be excluded from the population.

For logistical reasons, students attending a small number of schools were excluded. This included those attending Youthreach centres (an estimated 96 students), Senior Traveller programmes (estimated as 16 students), or island schools (estimated as 26 students). The estimated 50 students in privately funded schools (those which do not receive student capitation grants) were also excluded from the target population. Thus, the final national defined population of all 15-year-olds enrolled in grade 7 or higher in a mainstream DES school was 57,510 students. This is equivalent to a national desired population coverage (the total enrolled in educational institutions in grade 7 or higher, less any school-level exclusions) of 99.8%.

Sampling Methods and Response Rates

A two-stage stratified sample design was used to first select schools, then students. At the first stage, schools were stratified on a number of characteristics to ensure that those selected were representative of schools nationally. One explicit stratification variable (school size), and two implicit stratification variables (sector and gender composition) were used. This meant that schools were split into three groups, or strata, based on the number of 15-year-olds enrolled: small schools (less than 41), medium schools (41 to 80), and large schools (81+). Within these strata, schools were sorted by type (secondary, community/comprehensive, and vocational) and gender composition (females as a percentage of 15-year-olds enrolled, split into five categories).

In each explicit stratum, the number of schools selected was based on the number of students in that stratum in the population and the number in the expected sample. The probability of a school being selected was based on the number of 15-year-olds within the school. The greater the number, the greater the probability of selection (as the sampling technique of probability proportional to size, or PPS, was used). To generate a sufficiently large student sample, 165 schools were selected. With the exception of one selected school, which had subsequently closed down, all agreed to participate. This gives an initial school participation rate of 99.4%, without replacement.

At the second stage of sampling, students were selected within schools. In schools with fewer than 35 students aged 15, all eligible students were selected. In schools with larger enrolments, 35 students were randomly selected from a list of all eligible students within the school (lists were implicitly stratified by gender, grade level and month of birth to ensure that a representative sample of students was selected). In total, 5,680 students were selected.

Just over 4% of selected students were identified by principals as having special educational needs (i.e., a functional disability, a moderate or severe general learning disability, or a specific learning disability) or limited experience in the language of instruction. Most of these students were able to participate in the assessment, and only 92 students (1.6%) were excluded (Table 1.7). Of the total number of students selected to participate, close to 4% refused to take part (either parental or student refusal), while 1% had transferred to another school or did not fall within the correct age range. The whereabouts of 1% were unknown, meaning that they were not recorded as having transferred to another school, but were no longer attending the school in which they were selected. The main reason for student non-participation was absenteeism (12%), accounting for more non-participation than all other reasons combined.

Table 1.7: Reasons for non-participation (numbers and percentages of students)[2]

		N	% of total
Ineligible	Transferred to another school	42	0.7
	Not in school, location unknown	63	1.1
	Not age-eligible	13	0.2
Excluded	Special educational needs/limited language proficiency	92	1.6
Other	Refusal	202	3.6
	Absent	683	12.0
	Total non-participants	1095	19.3

Numbers are unweighted.

Reasons for absenteeism were not recorded by test administrators, but feedback suggests that while some was 'explained' (e.g., the assessment clashed with a practical exam), most was not. Overall, 4,585 selected students (80.7%) participated in the cognitive assessment and 4,514 (79.5%) responded to the student questionnaire. Once school and student participation rates were weighted and account taken of excluded and ineligible students, Ireland's weighted final response rate was 83.8%. Both student- and school-level response rates exceeded the minimum levels required for participation in PISA 2006 (80% and 85%, respectively).

[2] The numbers and percentages in the table and in the text refer to non-participation in the cognitive assessment. Data are slightly different for the student questionnaire.

The sampled schools included nine in which students received instruction through Irish. All materials were translated into Irish, and students in these schools were allowed to select the language in which to complete the test[3] and student questionnaire. Principals and science teachers in these schools were provided with questionnaires in both Irish and English. Twenty-three students (0.5% of those who participated) chose the Irish language versions of materials.

Administration of the Assessment

Trained test administrators (composed of ERC staff, teachers, and retired school inspectors) conducted the assessment in schools. Testing occurred over a three-week period from the middle of March to the first week of April. Most of the testing happened in the first two weeks, with the last week being used to accommodate schools which re-scheduled their test dates, and, in a small number of schools, students who could not attend on the original assessment date. Testing time was two hours for the cognitive assessment (with a short break after the first hour), with an additional 45 minutes allowed for completion of the student questionnaire. In almost all cases, test administration was completed in the morning. Test administrators liaised with a school co-ordinator (usually the principal or a science teacher) to ensure that the administration of PISA involved as little disruption as possible to the school. Principals and Junior Certificate science teachers were encouraged to have completed questionnaires ready for collection by the test administrator on the day of administration. A majority of questionnaires were returned in this manner, with the remainder mailed to the ERC.

The use of a rotated test design meant that students were asked only to respond to a portion of the total pool of test items. Test items were distributed across 13 assessment booklets, each containing approximately 70 items, with items repeated across booklets. Each assessment booklet contained science items, while mathematics items were in 10 booklets and reading in seven booklets. The PISA consortium employed two PISA quality monitors in Ireland. Their role was to monitor testing in schools, and to ensure that PISA standards were met. Sixteen test administrations were monitored. Generally, the administration of PISA 2006 in Ireland was judged to meet international standards. Student responses were scored by trained coders, all of whom had third-level qualifications. A subset of test booklets was scored by four coders, to examine inter-scorer reliability, and to ensure that coders adhered to scoring guidelines specified by the PISA consortium. These booklets and the four sets of scores were sent to the consortium for analysis and review. The as-yet-unpublished results indicate that the quality of marking in Ireland was high.

Scaling PISA 2006 Data

Test data were scaled using Item Response Theory (IRT). A one-parameter model was used, in three main phases. First, national item calibration took place, then international item calibration; and finally, scale scores were generated. The same

[3] Students could choose to complete the mathematics and science elements of the test in Irish or English. However, the reading test was a test of *English* reading, and could not be taken in Irish.

metric was used for item difficulty and student ability. This means that student ability at a given level can be described in terms of task characteristics of items associated with that level. As each student completed only a part of the assessment item pool, student ability was imputed using five 'plausible values'. Plausible values are random numbers that are drawn from the distribution of scale scores that could be reasonably assigned to each student. They contain random error variance components and are not ideal for reporting scores at the level of the individual student, but, provided all plausible values are used, are suitable for describing the performance of groups. Five plausible values were assigned to each student for each overall scale (science, mathematics, reading) and for each science subscale.

Plausible values were obtained by following a five-step procedure that has also been used in studies such as the Third International Mathematics and Science Study (TIMSS) (e.g., Macaskill, Adams and Wu, 1998). First, five 'conditioning variables' (student gender, maternal and paternal occupation, booklet ID, and school mean science score) were prepared. Second, each variable in the student questionnaire was dummy-coded. Third, a country-by-country principal components analysis of the dummy-coded variables, which produced component scores for each student, was carried out. The fourth step fitted the item-response model to each country's data, estimating national population parameters using item parameters anchored at their international location. Finally, five vectors of plausible values were drawn. In PISA 2006, not all students were assessed in all three domains. However, the plausible values for all three domains were used for all students. Thus, it was possible to impute scores for students on each domain, even if they had not responded to any test items in a particular domain. Readers who wish for more details are referred to the PISA 2006 Technical Report (OECD, in press).

Estimating Variance Associated with Achievement

As a two-stage, stratified sampling technique was used, variance estimation of student characteristics was likely to be underestimated. Therefore, Fay's Balanced Repeated Replication (BRR) method, which takes into account the clustered nature of the sample design, was used. Using this method, half of the sample is weighted by a K factor, which must be between 0 and 1 (set at 0.5 for PISA analyses), while the other half is weighted by 2−K.

How to Interpret the Analyses in This Report

Much of this report details the relationships between explanatory variables and achievement data (e.g., gender and performance on the scale of scientific literacy). Typically, two main table types are used to present data: one showing multiple comparisons of means, the other showing correlations. Correlations are used for continuous variables, while multiple comparison tables are used for categorical variables (e.g., gender) which are then compared to see if they differ significantly from each other. Inset 1.2 explains how to interpret correlations while Inset 1.3 explains how to interpret multiple comparison tables.

Inset 1.2: Interpreting Correlation Coefficients

The value of a correlation can range from –1 to +1. A negative correlation (e.g., r = –.34) means that as one variable increases in magnitude, the other decreases; a positive correlation (e.g., +.34) means that the values of both variables increase or decrease together. A value of 0 indicates that there is no association between two variables. The closer that *r* is to ±1, the stronger the relationship. To assist in interpreting correlations, we use the following qualitative labels:

- weak <± .1
- weak to moderate ± .1 to .24
- moderate ±.25 to .39
- moderate to strong ± .4 to .55
- strong ±.56 or greater

Inset 1.3: Comparing Mean Achievement Scores

Throughout this report, you will see tables comparing the mean achievement scores of various groups of students. In the tables, there are four columns of data (**% Total, % Available, Mean** and **SE**). The **% Total** column shows the percentages of students in a particular group, including those for whom only achievement data are available. In the example below, number of TVs in the home is unknown for 2.3% of students. The **% Available** column is equivalent to the valid percentage in each category – that is, the percentages of those for whom all information is available. Thus, while 17.2% of our total sample are known to have two TVs at home, 17.6% of those for whom we have information on TV ownership have two TVs at home.

Mean shows the average score on the PISA scale of scientific literacy for students in each group. In the example below, 78.3% of students for whom data were available had three or more TVs, and these students obtained a mean PISA science score of 504.4. The final column – **SE** – shows standard errors corresponding to the adjacent mean scores (e.g., the standard error of the mean score of students with three or more TVs is 3.0). The SE of a mean score is an estimate of the extent to which the score may be expected to vary about the 'true' mean, and, as such, is a measure of the accuracy of mean scores derived from a sample.

EXAMPLE: Mean science scores of Irish students, by number of TVs in the home

	Frequencies		Science	
	%Total	%Available	Mean	SE
None	0.3	0.3	495.7	27.7
One	3.7	3.8	**535.8**	11.8
Two	17.2	17.6	**527.3**	4.8
Three plus (Ref category)	76.5	78.3	504.4	3.0
Missing	2.3	0.0	**452.6**	10.9
All Available	97.7	100.0	509.6	3.2

Significant differences in bold.

Three or more TVs is flagged as the **reference category**, meaning that the performance of students in this group has been compared to the performance of students in each of the other groups. Where the performance of students in the reference group is significantly different from that of students in another group, mean scores for the other group are flagged using bold font. In the example above, students with one TV, two TVs, and students for whom TV data are missing are flagged as differing significantly (on science achievement) from students with three or more TVs. The table also shows data for **All available** (all students for whom information on the variable is available).

The statistical comparison is performed by using the mean score difference, the standard error of the difference, and 95% Bonferroni-adjusted confidence intervals. Full information on these, and a more detailed version of tables in this report – including data for reading and mathematics – are available on *ww.erc.ie/documents/pisa2006_e-appendix.pdf*.

Chapter 2
Achievement in Earlier International Studies

The purpose of this chapter is to provide a broad context in which to interpret the outcomes of PISA 2006. First, the chapter looks at the performance of students in Ireland in earlier international studies, with particular reference to science (the major assessment domain in PISA 2006). Secondly, it looks at school and student variables associated with achievement in earlier studies. Thirdly, links between curricula and performance in earlier studies are considered.

Readers are urged to exercise care in comparing outcomes of earlier studies. The performance of a country across studies may be linked to a range of factors including: differences in the target population (whether the sample is grade-based or age-based); coverage rates (whether or not all students in a country are eligible to participate); differences in the measurement instruments used; and differences in approaches to scaling the data. In studies such as PISA, in which performance is compared over several cycles, additional factors such as framework and item comparability over time, as well as the characteristics of the subset of items used to link performance need to be considered (OECD, 2007a). Where a country ranking is provided, readers should remember that not all countries ranked higher or lower than Ireland performed significantly differently from Ireland.

Achievement Outcomes in Earlier Studies

Ireland has participated in a number of international assessments relating to some or all of the PISA domains of scientific, mathematical, and reading literacy (Table 2.1). In this section, we focus on the performance of Irish post-primary students in recent international studies relating to the major PISA domain of scientific literacy. This is followed by a brief description of the performance of Irish students on mathematics and reading in previous PISA cycles.

Table 2.1: Ireland's participation in international assessments of achievement (1980-2006)

Year	Study	Areas Assessed	Population
1980-82	Second International Mathematics Study (SIMS)*	Mathematics	1st and 6th years
1989	International Assessment of Educational Progress I	Mathematics, Science	13-year-olds
1991	International Assessment of Educational Progress II	Mathematics, Science	9- and 13-year-olds
1991	IEA Reading Literacy Study	Reading Literacy	9- and 14-year-olds (3rd class, 2nd year)
1995	Third International Mathematics and Science Study (TIMSS)	Mathematics, Science	3rd/4th classes 1st/2nd years
2000 2003 2006	PISA	Reading, mathematical, and scientific literacy	15-year-olds

* Ireland took part in the curriculum analysis component of SIMS (see Oldham, 1989). Achievement data were gathered only for a follow-up study of First year students (Carey, 1990) and not analysed at international level.

Science Achievement

In the 1990s, Ireland participated in two international assessments at second level that included science – the Second International Assessment of Educational Progress (IAEP II) in 1991 (Lapointe, Askew & Mead, 1992; Martin, Hickey & Murchan, 1992) and the Third International Mathematics and Science Study (TIMSS) in 1995 (Beaton, Martin, Mullis, Gonzalez, Smith, & Kelly, 1996). Since then, Ireland has participated in PISA in 2000 and 2003. Science was a minor PISA domain on each occasion.

IAEP II Science

IAEP II, which was implemented in 1991, involved 13-year-olds in 21 countries/ regions. The science component comprised four science content areas (Life Sciences; Physical Sciences; Earth and Space sciences; and Nature of Science) and three science processes (Knows Science; Uses Science; and Integrates Science). Thirteen-year-olds in Ireland achieved a mean score of 63% correct, which was significantly below the international average (67%). Ireland ranked 14th of 15 countries with comprehensive sample population coverage (Martin et al., 1992), and 9th of 10 OECD countries (OECD, 1993). The highest achieving countries were Korea, Taiwan, and Switzerland. Irish 13-year-olds achieved scores that were not significantly lower than the corresponding international averages in two content areas (Nature of Science and Earth and Space Sciences), and were significantly below the international average in the other two. Scores did not differ from the international average on the three science processes.

TIMSS Science

TIMSS, which was implemented in 1995, involved students in First year (Grade 7) and Second year (Grade 8) in post-primary schools in 41 countries/regions. The science component comprised five content areas (Earth science; Life science; Physics; Chemistry; and Environmental issues and the nature of science) and five processes (Understanding, theorizing, analyzing and solving problems; Using tools; Routine procedures and science processes; Investigating the natural world; and Communicating). The performance of Irish students in First and Second year in TIMSS science was quite similar. As Second year is closest to the target group for PISA, we focus on the performance of Second year students. Students in Ireland achieved a mean score (539) that was not significantly different from the average of OECD countries in the study (537) (OECD, 1997, Chart F1.4). The highest scoring countries included Singapore, Korea, Japan and the Czech Republic. Students in Ireland scored significantly above the corresponding international average on two content areas (Earth science and Environmental issues and the nature of science), and not significantly different from the international average on the others. TIMSS did not provide data on performance on the five science processes.

PISA Science

PISA included science as a minor assessment domain in both 2000 and 2003. In 2000, 28 OECD countries and 15 'partner' countries took part;[1] in 2003, 30 OECD countries and 11 partners were involved. In both years, the test was based on frameworks that

[1] These include 11 'partner' countries that administered PISA 2000 in 2001.

focused more broadly on 'real life' science than was the case in the IAEP or TIMSS assessments. In 2003, for example, science items were drawn from 11 science knowledge areas (e.g., Earth and universe; Structure of matter; Energy transformations; Chemical and physical change) and three scientific processes (Describing, explaining and predicting scientific phenomena; Understanding scientific investigation; and Interpreting scientific evidence and conclusions). Unlike IAEP and TIMSS, performance was reported only in terms of overall scores as, in both 2000 and 2003, an insufficient number of science items was available with which to analyze performance in depth.

In PISA 2000, students in Ireland achieved a mean score of 513.4, which was significantly above the OECD country average of 500, and ranked 9th of 27 OECD countries[2] and 10th of all participating countries (OECD, 2001; Shiel et al., 2001). Korea, Japan, Hong Kong-China and Finland were among the highest-scoring countries. While students in Ireland scoring at the 10th percentile – often taken as a benchmark for the performance of lower-achieving students – achieved a score (394.4) that was significantly higher than the OECD average at that benchmark (368.5), students scoring at the 90th percentile achieved a score (630.2) that was not significantly different from the corresponding OECD average (626.9) (OECD, 2001, Table 3.3). The range of achievement in science in Ireland was narrower than in most OECD countries. If we examine the range between the 5th and 95th percentiles (i.e., 90% of the population), we find that the difference in Ireland (299.3) is smaller than the corresponding OECD country difference (324.8).

In PISA 2003, students in Ireland achieved a mean score (505.4) that was again higher than the OECD country average (499.6) (Cosgrove et al., 2005; OECD, 2004b). Ireland ranked 13th of 29 OECD countries[3], and 16th of 40 participating countries. The highest-performing countries in 2003 were Finland, Japan, Hong Kong-China and Korea. Lower-achieving students in Ireland (those scoring at the 10th percentile) achieved a score (383.9) that was significantly higher than the OECD country average (323.9) at that benchmark (OECD, 2004b). Higher achieving students (those scoring at the 90th percentile) achieved a score (624.5) that is significantly smaller than the corresponding OECD country average (634.2). As in 2000, the difference between the 5th and 95th percentiles in Ireland (304.4) was smaller than the OECD country average difference (343.6).

Although the OECD country average mean scores in 2000 (500.0) and 2003 (499.6) were not significantly different from one another, differences at OECD level were observed at the bottom of the achievement distribution (where scores at the 5th and 10th percentiles were significantly lower in 2003 than in 2000), and at the top (where scores at the 90th and 95th percentiles were significantly higher) (OECD, 2004b, Figure 6.12). These differences may reflect the inclusion of additional OECD countries (Turkey, Slovakia, The Netherlands) in the 2003 dataset, as well as the exclusion of the United Kingdom in the same year. In Ireland, neither the mean scores, nor the scores of students at these key benchmarks, differed between the two years.

---

[2] Data for The Netherlands were excluded due to school-level response problems.

[3] Data for the United Kingdom were excluded due to school- and student-level response problems.

PISA Mathematics

Mathematics was a minor assessment domain in PISA 2000 and a major domain in PISA 2003. In 2000, students in Ireland achieved a mean score of 502.9. This was not significantly different from the OECD country average of 500, and ranked Ireland 15th of 27 OECD countries and 16th of 41 participating countries (OECD/UNESCO-UIS, 2003). The highest-scoring countries were Hong Kong-China, Japan, and Korea. In Ireland, students scoring at the 5th percentile achieved a score (357.3) that was approximately 31.1 points above the corresponding OECD average (326.2), while students scoring at the 95th percentile achieved a score (629.7) that was 25.4 points below the corresponding OECD benchmark (655.1). The range of achievement (the difference between the 5th and 95th percentiles) was smaller in Ireland (272.4) than the average range across OECD countries (328.9). Similarly, the standard deviation in mathematics for Ireland (83.6) was lower than the OECD average standard deviation (100.0). As a minor domain, no data on proficiency levels were provided.

In PISA 2003, mathematics was a major assessment domain. This meant that mathematics was assessed using a more comprehensive framework and a greater number of items than in PISA 2000. Further, it was possible to describe performance by mathematics content area, as well as in terms of overall performance. The mean score of 15-year-olds in Ireland on the overall mathematics scale was 502.8, which was not significantly different from the OECD mean of 500.0[4] (Cosgrove et al., 2005; OECD, 2004b). Ireland ranked 17th of 29 OECD countries, and 20th of 40 participating countries. The highest performing countries included Hong Kong-China, The Netherlands, Finland, Canada and Korea.

The Irish mean scores on two subscales – Change & Relationships (506.0) and Uncertainty (517.2) – were significantly higher than the corresponding OECD average scores; the mean score on Quantity (501.7) was not significantly different; and the mean score on Space & Shape (476.2) was significantly lower. On the overall mathematics proficiency scale, 16.8% of students in Ireland achieved scores that were at or below Level 1 (the lowest level), compared with an OECD average of 21.4%. In contrast, just 11.3% of students in Ireland scored at the Levels 5 and 6 (the highest levels), compared with 14.6% on average across OECD countries.

A comparison was drawn between performance on PISA mathematics in 2000 and 2003, focusing on two subscales only – Space & Shape and Change & Relationships. Although a significantly higher performance was observed on Space & Shape in four OECD countries, and a decline in two, Ireland's mean score did not differ on the two assessments (OECD, 2004b, Figure 2.6c). Similarly, while there was an improvement in performance on Change & Relationships in 13 OECD countries and no declines in performance, Ireland's mean scores did not change over the two assessments (OECD, 2004b, Figure 2.9c).

[4] Unlike PISA 2003 science, PISA 2003 mathematics was rescaled to an OECD mean of 500 and a standard deviation of 100. This was judged to be necessary as PISA mathematics had moved from a minor to a major domain.

PISA Reading Literacy

Reading was a major assessment domain in PISA 2000 and a minor domain in 2003. In 2000, Ireland's mean score on the combined (overall) reading literacy scale was 526.7, significantly higher than the OECD average score of 500.0 (OECD, 2001). Ireland ranked 5th of 27 OECD countries, and only Finland achieved a significantly higher overall score. Students in Ireland also achieved mean scores that were above the international average on the three reading subscales – Retrieve, Interpret, and Reflect & Evaluate. On the last of these subscales, the difference in mean scores between Canada, the highest scoring country, and Ireland was not statistically significant. On the overall reading proficiency scale, 11.0% of students in Ireland achieved at or below Level 1 (the lowest level), compared with an OECD average of 17.9%. Similarly, 14.2% of students in Ireland achieved at Level 5[5] (the highest level), compared with an OECD average of 9.5%. Ireland's standard deviation on the combined scale (93.6) was lower than the OECD average of 100.0.

In PISA 2003, Ireland's mean score of 515.5 was significantly higher than the OECD average score, which dropped to 494.2 (OECD, 2004b). Ireland ranked 6th of 29 OECD countries, and 7th of 40 participating countries. Three countries (Finland, Korea, and Canada) had mean scores that were significantly higher than Ireland's. On the reading proficiency scale, 11.0% of students in Ireland achieved scores that were at or below Level 1, compared with an OECD average of 19.1%. Just over 9% of students in Ireland (9.3%) achieved at Level 5, compared with an OECD average of 8.3%.

The initial international report on PISA 2003 (OECD, 2004b) indicated that the drop of 11 scale points in Ireland's mean scores on reading literacy between 2000 and 2003 was statistically significant, and that performance at the 75th, 90th and 95th percentiles was also significantly lower in 2003. However, the initial international report on PISA 2006 (OECD, 2007b) indicated that the decline in mean scores was significant at the unconventional .10 level only, and not significant at the conventional .05 level.[6] The report confirmed that differences at the 75th, 90th and 95th percentile ranks were significant at the .05 level.

Variables Associated with Achievement

This section looks at variables associated with achievement in earlier international studies. First, associations between achievement and gender, home background, and attitude towards a subject are examined. Second, the use of hierarchical multi-level models to evaluate the association between a variable and achievement, while controlling for other, related variables is considered. In general, this section draws on national and international work conducted in earlier cycles of PISA.

Student Gender

Patterns of gender differences in PISA have been consistent over the first two cycles. In PISA 2000, female students in Ireland outperformed their male counterparts on

[5] Whereas there were 6 proficiency levels in PISA mathematics in 2003, there were 5 in PISA reading in both 2000 and 2003.

[6] The difference arose as a revised method was used to calculate the error associated with items used to link performance across the two assessment cycles.

combined reading literacy by 28.7 points – a difference that was almost identical to the OECD average difference (OECD, 2001). Finland had the largest difference (51.3 points in favour of females) and Korea the smallest (14.2 points in favour of females). The largest difference in favour of females in Ireland was on the Retrieve/Evaluate subscale (37.2 points), and the smallest on the Retrieve subscale (22.3). In PISA 2003, female students outperformed their male counterparts on the reduced overall scale by 29.0 points, compared with an OECD average difference of 34.1 points (OECD, 2004b).

In mathematics, male students in Ireland achieved a mean score on PISA 2000 that was significantly higher than that of females by 12.9 points (OECD, 2001). The corresponding OECD country average difference was 11.0 points. The largest difference in favour of males (27 points) was observed in Korea. In PISA 2003, male students in Ireland achieved a mean score on the expanded combined mathematics scale that was significantly higher than that of females, by 14.8 points (OECD, 2004b). This OECD average difference was 11.1 points. In most countries, male students outperformed females, or their mean scores did not differ significantly. However, in Iceland, females outperformed males by 15.4 points. In Ireland, the difference in favour of males was greatest on the Space & Shape subscale (25.5 points), and smallest (but still significant) on the Quantity subscale (8.9 points).

In science, the mean score difference between male and female students in Ireland in PISA 2000 (6.2 points) was not statistically significant (OECD, 2001). The OECD average difference was 0, with some countries showing a difference in favour of males (27 points in Korea) and others showing a difference in favour of females (12 points in New Zealand). In PISA 2003, male students in Ireland had a mean score that was higher (by 2.0 points) than females (OECD, 2004b). However, the difference was not statistically significant. Males outperformed females in just two countries (Iceland and Tunisia), while females outperformed males in 12.

In IAEP II, the mean percent correct science score of male students in Ireland (66%) was significantly higher than that of females (61%) – a pattern that held across all participating countries (Martin et al., 1992). Males in Ireland outperformed females on three subscales – Life Sciences, Physical Sciences, and Earth and Space sciences. There was no difference between genders on Nature of Science. In TIMSS 1995, the mean score of 60% in overall science achieved by Irish males in Second year did not differ significantly from the mean score of females (57%) (Beaton et al., 1996). Of the five science content areas in TIMSS 1995, male students in Ireland had a significantly higher mean score (59%) than females (54%) in just one area – Physics. Across participating countries, differences, where they arose, almost always favoured male students.

Student Home Background Variables

PISA has closely examined relationships between a range of home- related variables and achievement. In Ireland, in both PISA 2000 and PISA 2003, students with at least one parent who had completed a third-level course outperformed students whose parents had lower levels of education (upper secondary, lower secondary, or primary only) (Cosgrove et al., 2005; Shiel et al., 2001).

In PISA, student socioeconomic status is based on the highest occupation of either parent, and is coded on the International Socioeconomic Index (ISEI). In both 2000 and 2003, students in the top third of the ISEI scale in Ireland outperformed students in the middle and bottom thirds. In science in 2000, the difference in mean achievement between those in the top and middle thirds was over one-quarter of a standard deviation (Shiel et al., 2001). In 2003, the PISA Economic, Social and Cultural Status (ESCS) scale, which includes both ISEI and cultural possessions in the home, was also used (Cosgrove et al., 2005). The Irish mean on the scale was just below the international mean. In science, a difference of over one-third of a standard deviation was observed between students in the top and middle thirds of the distribution of ESCS scores.

Earlier PISA cycles also included measures of students' home educational resources (a composite measure that includes access to a desk for study, a quiet place to study, and availability of books to help with school work) and number of books in the home. Both measures are strongly associated with achievement. For example, in PISA 2003, students with over 500 books in the home had a mean science score that was over one-half of a standard deviation higher than that of students with 26-100 books (Cosgrove et al., 2005).

Family-related variables such as lone-parent status and number of siblings were also related to achievement in earlier PISA cycles. In PISA 2003, for example, students in lone-parent households achieved a mean score on science that was over one-quarter of a standard deviation lower than that of students in dual-parent households, while students with one sibling had a higher mean science score than students with no siblings, and students with three or more siblings (Cosgrove et al., 2005).

Student Dispositions

A feature of each PISA cycle is the development of student dispositional scales related to the main assessment domain. In PISA 2000 in Ireland, the correlation between an overall measure of attitude to reading and performance on the reading scale was 0.43 (Shiel et al., 2001). In PISA 2003, the correlation between a measure of anxiety about mathematics and mathematics achievement was −0.36 (Cosgrove et al., 2005). In the same cycle, the correlation between self-efficacy in mathematics and mathematics achievement was 0.53, indicating that students who were confident about their ability to succeed on mathematics tasks tended to perform better. Care needs to be exercised in interpreting associations between dispositional variables and achievement, as is often unclear how the association operates in practice.

Other Student Variables

Among the other variables that have been shown to be associated with achievement in earlier PISA cycles are student attendance rates (students who had poor attendance in the two weeks preceding the PISA assessment tend to do less well), grade level (Transition and Fifth years tend to obtain the highest scores), intention to leave school early (those planning to complete the Leaving Certificate perform best), and syllabus level (students taking a subject at Higher level do better in the corresponding PISA domain). A key finding in both PISA 2000 and PISA 2003 was that students in Ireland who studied Ordinary level science did not perform significantly differently from those who had not studied science (Cosgrove et al., 2005; Shiel et al, 2001).

School-level Variables

Among the school-level variables that have been shown to be related to achievement are school size (in PISA 2003, larger schools did better than medium sized schools on all three domains), school sector (secondary schools generally did better than community/comprehensive and vocational schools), school designated disadvantaged status (designated schools did less well), and aggregate school socioeconomic status (schools in the top third of the PISA ESCS distribution outperformed those in the middle and bottom thirds on all three assessment domains) (Cosgrove et al, 2005). Other school level variables associated with achievement are the average disciplinary climate in mathematics classes, school resources (the ratio of computers to students), and the student:teacher ratio.

Explanatory Models of Performance on PISA

In both PISA 2000 and PISA 2003, multi-level models of performance were developed to take account of the clustered nature of the data and to help explain the association between school and student variables and achievement. In PISA 2003, a multi-level model of Irish students' science performance explained 80.6% of between-school variance in achievement, and 31.2% of within-school variance (Cosgrove et al., 2005). The final model included two school-level variables (both main effects) – disciplinary climate in mathematics classes and the percentage of students with a Junior Certificate examination fee waiver (a measure of school-level socioeconomic status). Student level variables in the model included gender (with a significant difference of 8 points in favour of females)[7], socioeconomic status, lone-parent status, number of siblings, number of books in the home, home educational resources, grade level, whether or not the student studied science, and frequency of absence from school. The model was broadly similar to a model of science performance based on PISA 2000 (Shiel et al., 2001), which explained roughly similar proportions of between- and within-school variance. However, the 2000 model included school sector (secondary, community/comprehensive, vocational) and school designated disadvantaged status at the school level, and a measure of parental engagement with their children at the student level. Together, the models demonstrate the combined effects of school- and student socioeconomic status on student performance, as well as the role of home educational resources.

Associations Between Curriculum and Performance

Earlier international studies, including IAEP II and TIMSS 1995, sought to establish associations between the emphasis placed on particular topics by curricula and/or teachers and performance. In IAEP II, for example, principal teachers were asked to indicate the emphasis placed on various science topics (Martin et al, 1992), while TIMSS 1995 organised a test-curriculum matching analysis, and reported country-level performance on those sets of items that were addressed in a country's curriculum, and on the full item set (Beaton et al, 1996). In Ireland, performance on TIMSS science in Second year was higher (62% correct) on those items that were judged to be on the science curriculum, compared with the full item set (58%).

---

[7] This contrasts with the earlier finding of no significant difference between males and females in PISA 2003 science.

Although, at international level, PISA does not attempt to establish an association between curriculum coverage and performance, in both 2000 and 2003, test-curriculum linking exercises were carried out in Ireland. Their purpose was to determine the extent to which the contexts/applications and processes underlying PISA reading, mathematics and science were represented in the Junior Certificate English, mathematics and science syllabi/examinations, and to examine associations between the extent of overlap and performance on PISA. Ratings were done by panels of experts in curriculum (syllabus development) and assessment who also had extensive teaching experience in their subject specializations.

In PISA 2000, the correlation between process familiarity and performance on reading literacy was 0.55, while the correlation between context familiarity and performance was 0.54 (Shiel et al., 2001). In the case of mathematics, the overall correlation between concept familiarity and performance was 0.48, while that between context/application and performance was 0.23. Hence, concept familiarity was a stronger predictor of performance in mathematics than the context in which an item was embedded. For science, the overall correlations between concepts and performance (0.19) and between processes and performance processes (0.05) were lower than for the other domains, while the correlation between contexts and performance (−0.01) was not statistically significant. Hence, for students in Ireland, the extent of overlap between PISA and the Junior Certificate Science syllabus was less predictive of performance than in the case of English or mathematics (Shiel et al., 2001).

In PISA 2003, a curriculum rating exercise was conducted only for mathematics, as this was the major assessment domain. While overall ratings for content were similar to 2000, greater percentages of items were deemed to be familiar in terms of context, reflecting a somewhat different emphasis in the presentation of some PISA items. The overall correlation between concept familiarity and PISA mathematics was .37 (weaker than in 2000), while for context it was .21 (almost the same as in 2000). A global rating that incorporated concept, context and format correlated 0.32 with mathematics. The content area with which students in Ireland were expected to be least familiar in terms of underlying concepts (Uncertainty) was one in which they performed well above the OECD average. However, students in many other countries were likely to be equally unfamiliar with the scale. Neither reading literacy nor science was examined in terms of curriculum familiarity in 2003.

Chapter 3
Science Achievement

In this chapter, we examine the performance of Irish students on the PISA assessment of scientific literacy, relative to the performance of students in other participating countries. There are seven main sections in the chapter. First, we present performance on overall scientific literacy. Next, we describe performance on the science competency scales (*identifying scientific issues, using scientific evidence* and *explaining phenomena scientifically*). In the third section, we describe 'proficiency levels' for science, overall, and for each of the competencies. The fourth section summarises performance on *knowledge about science* and *knowledge of science*. The fifth compares performance across scales. The sixth section examines gender differences on overall scientific literacy and on science subscales. The seventh outlines trends in Irish performance on PISA science.

Inset 3.1: How to Compare Mean Achievement Scores

You can use tables like Table 3.1 (overleaf) to compare mean achievement scores. It shows the mean score, standard error, and standard deviation (see *Statistical Terms Used*) for participating countries. Countries are sorted in descending order by their mean scores. Two types of comparisons are shown: mean score relative to Ireland and relative to the OECD. Shading denotes performance relative to Ireland:

- [black] = significantly higher than Ireland
- [white] = not significantly different from Ireland
- [grey] = significantly lower than Ireland.

Use the **OECD diff** column to compare a country's performance to the OECD average. The symbol ▲ denotes a significantly higher mean score, **O** denotes a mean score that does not differ significantly from the OECD average, and ▼ denotes a significantly lower mean score.

If you want to make other types of comparisons – e.g., between Germany and the UK – you need to examine the *standard errors* as well as the means. PISA produces *estimates* of country-level performance, based on the samples of each country's population of 15-year-olds. The standard error can be used to gauge the precision of such estimates. Assuming a normal distribution, we can create a *95% confidence interval* for a statistic as follows:

Statistic $\pm$ *1.96 standard errors*

The confidence interval is the resulting range, into which we would expect a statistic to fall 95% of the time were we to use many repeated samples. For example, in PISA 2006 Irish students obtained a science mean score of 508.3, with a standard error of 3.19. Thus, we can state with 95% confidence that the 'true' Irish population mean lies between 502.0 and 514.5 (i.e., 508.3 +/– 1.96 X 3.19). When examining whether the mean scores of countries differ significantly, always consider the associated standard errors. The larger they are, the larger the gap required for a difference to be significant.

The table assumes that single comparisons are being made. In fact, many are made, so the likelihood of finding a significant difference by chance is well above the conventional 5% level. While the Bonferroni adjustment for multiple comparisons was used in PISA 2000 and 2003, the increase in participating countries meant the adjustment was becoming increasingly stringent. Further, the difference between two countries with the same 'gap' in mean scores might be adjudged significant in 2003 but not in 2006. Thus, the OECD dropped the Bonferroni adjustment in 2006. In practical terms, this means that countries on the borders of shaded zones and with relatively large standard errors cannot confidently be distinguished from the Irish mean. A similar caveat applies when comparing countries with the OECD mean.

Performance on Overall Scientific Literacy

Ireland achieved a mean score of 508.3 on the overall science scale, significantly higher than the OECD average of 500. Consequently, Ireland is shown with ▲ in the OECD Diff column in Table 3.1. 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, Ireland's true rank is between 10th and 16th among OECD countries. Twelve countries (shown by dark shading, and including Finland, Hong Kong-China, Canada, and Estonia) have a significantly higher mean score. Nine countries (unshaded, 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 paler shading and including Denmark, France and the US) have mean scores that are significantly lower.

Table 3.1: Mean achievement scores, standard errors and standard deviations on the overall scientific literacy scale

	Mean	SE	SD	OECD Diff		Mean	SE	SD	OECD Diff
Finland	563.3	2.0	86	▲	Spain	488.4	2.6	91	▼
Hong Kong-China	542.2	2.5	92	▲	*Lithuania*	488.0	2.8	90	▼
Canada	534.5	2.0	94	▲	Norway	486.5	3.1	96	▼
Chinese Taipei	532.5	3.6	94	▲	Luxembourg	486.3	1.1	97	▼
Estonia	531.4	2.5	84	▲	*Russian Fed.*	479.5	3.7	90	▼
Japan	531.4	3.4	100	▲	Italy	475.4	2.0	96	▼
New Zealand	530.4	2.7	107	▲	Portugal	474.3	3.0	89	▼
Australia	526.9	2.3	100	▲	Greece	473.4	3.2	92	▼
Netherlands	524.9	2.7	96	▲	*Israel*	453.9	3.7	111	▼
Liechtenstein	522.2	4.1	97	▲	*Chile*	438.2	4.3	92	▼
Korea	522.1	3.4	90	▲	*Serbia*	435.6	3.0	85	▼
Slovenia	518.8	1.1	98	▲	*Bulgaria*	434.1	6.1	107	▼
Germany	515.6	3.8	100	▲	*Uruguay*	428.1	2.7	94	▼
United Kingdom	514.8	2.3	107	▲	Turkey	423.8	3.8	83	▼
Czech Republic	512.9	3.5	98	▲	*Jordan*	422.0	2.8	90	▼
Switzerland	511.5	3.2	99	▲	*Thailand*	421.0	2.1	77	▼
Macao-China	510.8	1.1	78	▲	*Romania*	418.4	4.2	81	▼
Austria	510.8	3.9	98	▲	*Montenegro*	411.8	1.1	80	▼
Belgium	510.4	2.5	100	▲	Mexico	409.7	2.7	81	▼
Ireland	508.3	3.2	94	▲	*Indonesia*	393.5	5.7	70	▼
Hungary	503.9	2.7	88	o	*Argentina*	391.2	6.1	101	▼
Sweden	503.3	2.4	94	o	*Brazil*	390.3	2.8	89	▼
Poland	497.8	2.3	90	o	*Colombia*	388.0	3.4	85	▼
Denmark	495.9	3.1	93	o	*Tunisia*	385.5	3.0	82	▼
France	495.2	3.4	102	o	*Azerbaijan*	382.3	2.8	56	▼
Croatia	493.2	2.4	86	▼	*Qatar*	349.3	0.9	84	▼
Iceland	490.8	1.6	97	▼	*Kyrgyzstan*	322.0	2.9	84	▼
Latvia	489.5	3.0	84	▼	OECD total	490.8	1.2	104	
United States	488.9	4.2	106	▼	OECD average	500.0	0.5	95	
Slovak Republic	488.4	2.6	93	▼					

(dark shading)	Mean significantly higher than Ireland	▲	Above OECD average
(no shading)	Mean not significantly different from Ireland	o	At OECD average
(pale shading)	Mean significantly lower than Ireland	▼	Below OECD average

OECD countries are in regular font; partner countries are in italics.

Spread of Achievement on Overall Science

As well as average performance, we can compare the spread of scores within countries. Similarities at the average level can hide quite different patterns of achievement between countries. For example, a country where most students perform very close to the mean can have a similar mean to a country with larger numbers of very low and very high achievers. Therefore, we also examine the gap between the scores of those at the 5th and 95th percentiles. This gap describes the range into which 90% of students in a country fall (a more reliable measure of the spread of achievement within a country than the highest and lowest scores). Scores *at* the 5th percentile can be used to represent very low-achieving students and scores *at* the 95th to represent very high-achieving students.

Table 3.2 shows science scores at key percentile indicators (5th, 10th, 25th, 75th, 90th, and 95th), sorted in descending order by mean score on the science scale. For space reasons, and for ease of reading, the table shows data for a subset of countries only. As well as Ireland, the countries selected for inclusion are the five countries with the highest mean scores on the scale, and a set of 'comparison countries' (Denmark, Germany, New Zealand, Poland, the US, and the countries composing the UK). The comparison countries are shown in all tables relating to key percentile markers and to proficiency levels, as – apart from the top-performing countries – they are judged to be the countries with which Ireland is most likely to be compared.

On the overall science scale, the gap of 309 points between Irish students at the 5th (very low achievers) and 95th (very high achievers) percentiles is very close to the OECD average of 311 points (Table 3.2). Of countries shown in Table 3.2, the smallest spreads of achievement between the 5th and 95th percentiles are found in Finland (281 points) and Estonia (276), while the largest spread is found in Northern Ireland (367).

Table 3.2: Percentage of students at key percentile markers on the overall science scale in Ireland, the five highest performing countries, and selected comparison countries

	Mean	5th		10th		25th		75th		90th		95th	
		Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Finland	563.3	419	4.4	453	3.3	506	2.9	622	2.5	673	2.9	700	3.1
Hong Kong-Ch	542.2	380	6.2	418	6.1	482	3.6	609	2.8	655	3.5	682	3.1
Canada	534.5	372	4.7	410	3.7	472	2.5	601	2.2	651	2.4	681	2.8
Ch. Taipei	532.5	369	4.5	402	5.0	466	5.3	602	3.4	651	2.7	676	3.4
Estonia	531.4	392	4.7	422	3.8	474	3.2	589	3.1	640	3.3	668	3.7
N. Zealand	530.4	347	5.2	389	4.5	455	3.6	608	2.9	667	3.3	699	3.1
Germany	515.6	345	8.1	381	7.0	447	5.3	587	3.6	642	3.2	672	3.6
England	515.6	336	6.8	375	5.1	442	3.6	592	3.3	653	3.5	686	3.8
Scotland	514.7	350	7.5	387	6.4	446	4.7	585	5.2	646	5.8	679	6.7
Ireland	508.3	351	5.8	385	4.4	444	4.6	575	3.4	630	3.7	660	4.9
N. Ireland	508.1	320	6.4	359	4.9	428	4.8	590	4.9	652	3.3	686	4.5
Wales	504.7	339	5.9	373	5.6	433	4.2	577	4.3	638	5.2	673	5.7
OECD	500.0	340	1.0	375	0.9	434	0.7	568	0.6	622	0.7	652	0.8
Poland	497.8	352	3.8	381	2.9	434	2.7	562	3.1	615	3.3	645	3.3
Denmark	495.9	341	5.9	373	4.8	432	4.3	562	2.9	615	3.7	646	4.3
US	488.9	318	4.5	349	5.9	412	5.4	567	4.6	628	4.3	662	4.8

The mean score of Irish students at the 5th percentile (351) is 11 points higher than the OECD average of 340 at the same marker. Thus, Ireland's lower-achieving students are performing slightly better than the OECD average, and Ireland has the 9th highest score at this marker among OECD countries. By way of contrast, students in Northern Ireland have a mean science score of 508, which is almost identical to that of students in the Republic of Ireland. However, Northern Irish students at the 5th percentile obtained a mean of 320, 31 points lower than the 351 obtained by students in the rest of the island. At the other extreme, students at the 95th percentile in the Republic obtained a mean of 660, which is slightly above the OECD average of 652 at that marker, but well below the score of 686 obtained by Northern Irish students at the 95th percentile.

Performance on Science Competencies

As well as an overall scientific literacy score, PISA provides scores on three science competency subscales (*identifying scientific issues*, *explaining phenomena scientifically*, *using scientific evidence*).

Identifying Scientific Issues

Ireland achieved a mean score of 515.9 on the *identifying scientific issues* scale, significantly higher than the OECD average of 498.8. Consequently, Ireland is shown with ▲ in the OECD Diff column in Table 3.3. Ireland's mean score is the 11th highest of the 57 participating countries, and the 8th highest of the 30 OECD countries. Applying a 95% confidence interval, Ireland's true rank is between 6th and 12th among OECD countries. Only six countries (Finland, New Zealand, Australia, The Netherlands, Canada and Hong Kong-China) have a significantly higher mean score. Eleven countries (unshaded, and including Estonia, the UK, and Germany) have mean scores that do not differ significantly from Ireland[1]. All remaining countries (including Denmark, the US, Norway, and Poland) obtained significantly lower mean scores than Ireland.

Readers may notice that while Iceland has a higher mean score than Croatia, Denmark and the United States, Iceland is shown with ▼ in the OECD diff column, while the other three countries are shown as not differing significantly from the OECD average. This is because the relatively small standard error associated with the Icelandic mean creates a smaller confidence interval (and more precise estimate) than is the case for Croatia, Denmark or the United States.

---

[1] Multiple comparisons of country means on the science competency scales are not contained in the initial OECD report, but are available from *www.pisa.oecd.org*

Table 3.3: Mean achievement scores, standard errors and standard deviations on the identifying scientific issues scale

	Mean	SE	SD	OECD Diff		Mean	SE	SD	OECD Diff
Finland	554.9	2.3	84	▲	Poland	483.1	2.5	84	▼
New Zealand	536.2	2.9	106	▲	Luxembourg	482.8	1.1	92	▼
Australia	535.3	2.3	98	▲	Hungary	482.7	2.6	81	▼
Netherlands	532.6	3.3	103	▲	*Lithuania*	476.1	2.7	84	▼
Canada	531.9	2.3	97	▲	Slovak Rep.	475.0	3.2	96	▼
Hong Kong-China	527.8	3.2	101	▲	Italy	474.2	2.2	99	▼
Liechtenstein	522.3	3.7	91	▲	Greece	468.8	3.0	92	▼
Japan	522.1	4.0	106	▲	*Russian Fed.*	462.9	4.2	89	▼
Korea	519.1	3.7	91	▲	*Israel*	457.0	3.9	114	▼
Slovenia	517.1	1.4	87	▲	*Chile*	444.1	4.1	89	▼
Ireland	515.9	3.3	95	▲	*Serbia*	430.5	3.0	83	▼
Estonia	515.6	2.6	77	▲	*Uruguay*	428.7	3.0	95	▼
Belgium	515.1	2.7	100	▲	Turkey	427.5	3.4	79	▼
Switzerland	514.9	3.0	95	▲	*Bulgaria*	427.3	6.3	109	▼
United Kingdom	513.8	2.3	106	▲	Mexico	421.4	2.6	85	▼
Germany	509.8	3.8	98	▲	*Thailand*	413.2	2.5	83	▼
Chinese Taipei	508.6	3.7	95	▲	*Romania*	409.5	3.6	77	▼
Austria	505.1	3.7	90	o	*Jordan*	408.8	2.8	89	▼
Czech Republic	500.5	4.2	99	o	*Colombia*	402.5	3.4	96	▼
France	499.2	3.5	104	o	*Montenegro*	401.1	1.2	83	▼
Sweden	498.6	2.6	96	o	*Brazil*	398.2	2.8	93	▼
Iceland	493.8	1.7	103	▼	*Argentina*	395.4	5.7	100	▼
Croatia	493.5	2.6	86	o	*Indonesia*	393.0	5.6	77	▼
Denmark	493.3	3.0	90	o	*Tunisia*	383.8	3.8	88	▼
United States	492.1	3.8	100	o	*Azerbaijan*	352.8	3.1	66	▼
Macao-China	490.1	1.2	79	▼	*Qatar*	352.4	0.8	79	▼
Norway	489.1	3.1	94	▼	*Kyrgyzstan*	321.3	3.2	93	▼
Spain	488.8	2.4	89	▼	OECD total	491.0	1.1	102	
Latvia	488.6	3.3	83	▼	OECD average	498.8	0.5	95	
Portugal	486.5	3.1	91	▼					

(black)	Mean significantly higher than Ireland	▲	Above OECD average
(white)	Mean not significantly different from Ireland	o	At OECD average
(grey)	Mean significantly lower than Ireland	▼	Below OECD average

OECD countries are in regular font; partner countries are in italics.

Table 3.4 shows scores at key percentile indicators on the *identifying scientific issues* scale. The gap of 311 points between Irish students at the 5th and 95th percentile is very close to the OECD average of 309 points. Of countries shown in Table 3.4, the smallest spreads of achievement between the 5th and 95th percentiles are found in Finland (275 points) and Poland (276), while the largest spread is found in Northern Ireland (353).

The mean score of Irish students at the 5th percentile (357) is 18 points higher than the OECD average at the same marker. Thus, Ireland's lower-achieving students are performing somewhat better than the OECD average, and Ireland has the 6th highest score at this marker among OECD countries. However, in Finland, students at the 5th percentile obtained a mean score of 411, one half of a standard deviation higher than the score obtained by Irish students at that marker.

The spread of achievement in Ireland on *identifying scientific issues* can be contrasted with the spread in England. Although the English mean of 515 is very similar to the Irish mean, English students at the 5th percentile obtained a score that is 20 points lower than that obtained by Irish students. At the other extreme, Irish students at the 95th percentile obtained a mean of 668. While this is 20 points above the OECD average at that marker, it is 15 points below the mean of English students at the same benchmark. Thus, the range of achievement is more truncated in Ireland than in England, with fewer very low- and very high- achieving students.

The performance of Finnish students is of particular interest. Finland's very high mean score on *identifying scientific issues* is not attributable to a cohort of very high-achieving students (for example, both Dutch and Australian students obtained higher scores at the 95th percentile). Rather, the Finnish mean is raised by the (relatively speaking) very high score of 411 obtained by students at the 5th percentile. In terms of *identifying scientific issues*, Finland's lowest-achieving students are performing at a similar level to the average student in countries such as Romania and Thailand.

Table 3.4: Percentage of students at key percentile markers on the identifying scientific issues scale in Ireland, the five highest performing countries, and selected comparison countries

	Mean	5th		10th		25th		75th		90th		95th	
		Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Finland	554.9	411	4.0	446	3.5	501	3.1	612	2.9	659	2.8	686	3.2
N. Zealand	536.2	356	4.8	396	4.8	465	4.3	612	3.0	668	3.0	701	3.5
Australia	535.3	368	4.3	406	3.1	471	2.7	604	2.8	658	3.2	689	3.6
Netherlands	532.6	360	7.3	397	5.7	462	4.5	606	3.5	662	4.0	694	4.5
Canada	531.9	363	4.9	404	4.1	469	2.9	599	2.3	652	2.5	683	2.9
Ireland	515.9	357	5.7	391	4.9	450	4.0	584	3.3	638	3.4	668	4.4
Scotland	515.9	351	6.2	388	6.5	448	5.0	583	4.5	648	5.8	682	7.5
England	514.7	337	7.3	377	5.3	444	3.5	588	3.1	649	3.4	683	3.7
Germany	509.8	341	8.3	381	6.6	444	5.0	579	3.4	630	3.5	660	4.0
N. Ireland	504.0	320	7.1	361	6.9	430	5.1	583	4.5	641	4.3	674	6.4
Wales	500.3	336	6.2	370	4.8	430	4.0	572	4.0	631	4.1	665	5.4
OECD	498.8	339	1.1	375	0.9	436	0.7	565	0.6	618	0.7	648	0.8
Denmark	493.3	341	5.5	375	4.5	432	4.0	556	3.2	607	3.2	637	4.4
US	492.1	330	5.8	362	5.3	420	4.7	563	4.2	621	4.9	654	5.2
Poland	483.1	344	3.9	374	3.2	425	3.0	542	3.2	591	2.7	619	3.7

Explaining Phenomena Scientifically

Ireland achieved a mean score of 505.5 on the *explaining phenomena scientifically* scale, not significantly different from the OECD average of 500.4. Thus, Ireland is shown with **0** in the OECD Diff column in Table 3.5. 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, Ireland's true rank is between 13th and 19th among OECD countries. Seventeen countries (ranging from Finland and Hong Kong-China to the UK, Austria and Liechtenstein) have a significantly higher mean score.

Seven countries (unshaded, and including Korea, Poland and Denmark) have mean scores that do not differ significantly from Ireland. All remaining countries (including Norway, Spain, and the US) obtained significantly lower mean scores than Ireland.

Table 3.5: Mean achievement scores, standard errors and standard deviations on the explaining phenomena scientifically scale

	Mean	SE	SD	OECD Diff		Mean	SE	SD	OECD Diff
Finland	566.2	2.0	88	▲	*Latvia*	486.3	2.9	88	▼
Hong Kong-China	549.3	2.5	94	▲	United States	486.1	4.3	110	▼
Chinese Taipei	545.2	3.7	101	▲	*Russian Fed.*	483.3	3.4	90	▼
Estonia	540.6	2.6	91	▲	Luxembourg	483.2	1.1	97	▼
Canada	530.9	2.1	100	▲	France	481.1	3.2	100	▼
Czech Republic	527.5	3.5	102	▲	Italy	479.5	2.0	100	▼
Japan	527.3	3.1	97	▲	Greece	476.5	3.0	93	▼
Slovenia	522.8	1.5	105	▲	Portugal	469.4	2.9	87	▼
New Zealand	522.2	2.8	111	▲	*Bulgaria*	444.3	5.8	105	▼
Netherlands	521.8	2.7	95	▲	*Israel*	443.4	3.6	109	▼
Australia	520.2	2.3	102	▲	*Serbia*	440.8	3.1	90	▼
Macao-China	520.0	1.2	83	▲	*Jordan*	437.6	3.1	98	▼
Germany	519.1	3.7	103	▲	*Chile*	432.1	4.1	94	▼
Hungary	518.1	2.6	94	▲	*Romania*	425.8	4.0	83	▼
United Kingdom	516.6	2.3	110	▲	Turkey	423.0	4.1	86	▼
Austria	516.4	4.0	100	▲	*Uruguay*	422.9	2.9	99	▼
Liechtenstein	516.2	4.1	97	▲	*Thailand*	419.9	2.1	75	▼
Korea	511.6	3.3	91	▲	*Montenegro*	416.7	1.1	82	▼
Sweden	509.8	2.9	99	▲	*Azerbaijan*	412.0	3.0	63	▼
Switzerland	507.8	3.3	102	▲	Mexico	406.2	2.7	83	▼
Poland	506.0	2.5	95	▲	*Indonesia*	394.6	5.1	72	▼
Ireland	505.5	3.2	100	o	*Brazil*	390.2	2.7	91	▼
Belgium	502.7	2.5	102	o	*Argentina*	386.5	6.0	104	▼
Denmark	501.3	3.3	96	o	*Tunisia*	383.4	2.9	83	▼
Slovak Republic	501.1	2.7	97	o	*Colombia*	379.0	3.4	90	▼
Norway	495.2	3.0	101	o	*Qatar*	356.0	1.0	88	▼
Lithuania	494.5	3.0	96	o	*Kyrgyzstan*	333.8	3.1	85	▼
Croatia	492.5	2.5	87	▼	OECD average	500.4	0.5	98	
Spain	490.3	2.4	98	▼	OECD total	489.1	1.2	107	
Iceland	488.1	1.5	92	▼					

(black)	Mean significantly higher than Ireland	▲	Above OECD average
(white)	Mean not significantly different from Ireland	o	At OECD average
(grey)	Mean significantly lower than Ireland	▼	Below OECD average

OECD countries are in regular font; partner countries are in italics.

Table 3.6 shows scores at key percentile indicators on the *explaining phenomena scientifically* scale. The gap of 328 points between Irish students at the 5th and 95th percentile is close to the OECD average of 320 points. Of countries shown in Table 3.6, the smallest spreads of achievement between the 5th and 95th percentiles are found in

Finland (288 points) and Estonia (295), while the largest spreads are found in Northern Ireland (367 points) and New Zealand (362).

Irish students at the 5th percentile on *explaining phenomena scientifically* obtained a mean score that is almost identical to the OECD average at the same marker (340 and 339, respectively). However, at the 95th percentile, Irish students obtained a mean score (668) that is 10 points higher than the equivalent OECD average score (658). Thus, for *explaining phenomena scientifically* Ireland's lower-achieving students are performing similar to the OECD average, while Ireland's higher achievers are performing slightly better than the average in OECD countries.

Finland's very high mean score on *explaining phenomena scientifically* is attributable to students at both the 5th and 95th percentiles obtaining far higher scores than corresponding average scores across OECD countries. For example, the mean score of 420 obtained by students at the 5th percentile on this scale in Finland is 27 points higher than the *next highest* performing country (Estonia) at this marker, and 81 points higher than the OECD average. Finland's lowest-achieving students obtain a score on *explaining phenomena scientifically* that is reasonably similar to the national mean scores in two OECD countries (Mexico and Turkey).

Table 3.6: Percentage of students at key percentile markers on the explaining phenomena scientifically scale in Ireland, the five highest performing countries, and selected comparison countries

	Mean	5th		10th		25th		75th		90th		95th	
		Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Finland	566.2	420	4.8	452	3.3	506	2.6	626	2.5	679	2.8	709	4.0
Hong Kong-China	549.3	387	7.0	423	5.0	488	3.4	615	2.7	667	3.3	695	3.9
Chinese Taipei	545.2	373	4.5	407	5.0	474	5.7	619	3.9	673	3.4	702	3.4
Estonia	540.6	393	5.1	422	3.1	477	3.2	604	3.2	658	3.5	688	3.7
Canada	530.9	362	4.4	400	3.4	464	2.8	601	2.5	657	2.4	689	2.6
New Zealand	522.2	339	5.9	378	4.3	445	3.6	601	3.2	664	3.1	700	4.1
Germany	519.1	345	6.8	381	6.2	448	5.5	592	3.8	651	3.6	684	4.6
England	518.2	340	5.4	376	4.0	441	3.6	596	3.5	662	4.1	698	4.2
N. Ireland	510.0	324	6.7	361	5.6	430	4.6	590	4.3	654	4.6	691	6.6
Scotland	508.3	345	6.4	378	6.2	435	5.0	579	5.6	645	5.7	683	6.0
Wales	508.2	339	6.1	373	5.1	433	4.2	582	4.5	648	5.4	684	6.7
Poland	506.0	353	4.4	384	3.8	438	2.8	572	3.3	630	3.2	664	3.8
Ireland	505.5	340	6.1	377	5.0	436	4.1	575	3.9	635	3.9	668	4.4
Denmark	501.3	342	5.1	376	5.0	435	4.0	568	3.6	627	3.8	658	4.2
OECD	500.4	339	1.0	373	0.9	433	0.7	569	0.6	626	0.7	658	0.9
US	486.1	311	5.5	345	5.2	404	5.5	565	4.8	632	4.6	670	6.0

Using Scientific Evidence

Ireland's mean score of 505.9 on the *using scientific evidence* scale is slightly (but significantly) higher than the OECD average of 499.2 (Table 3.7). Ireland ranks 19th of the 57 participating countries, and the 13th highest of the 30 OECD countries. Applying a 95% confidence interval, Ireland's true rank is between 11th and 15th among OECD countries. Fourteen countries (shown in black, and including Finland, Japan, Hong Kong-China, and Belgium) have a significantly higher mean score. Seven countries (including Germany, the UK, France, and Hungary) have mean scores that do not differ significantly from Ireland. All remaining countries (including Sweden, Poland, Denmark, and the US) obtained significantly lower mean scores than Ireland.

Table 3.7: Mean achievement scores, standard errors and standard deviations on the using scientific evidence scale

	Mean	SE	SD	OECD Diff		Mean	SE	SD	OECD Diff
Finland	567.4	2.3	96	▲	*Lithuania*	486.5	3.1	99	▼
Japan	544.3	4.2	116	▲	Spain	484.8	3.0	101	▼
Hong Kong-China	542.4	2.7	99	▲	*Russian Fed.*	480.8	4.2	102	▼
Canada	541.5	2.2	99	▲	Slovak Rep.	477.6	3.3	108	▼
Korea	538.5	3.7	102	▲	Norway	472.6	3.6	109	▼
New Zealand	536.8	3.3	121	▲	Portugal	472.2	3.6	103	▼
Liechtenstein	534.9	4.3	111	▲	Italy	467.0	2.3	111	▼
Chinese Taipei	531.8	3.7	100	▲	Greece	465.4	4.0	107	▼
Australia	531.3	2.4	107	▲	*Israel*	460.3	4.7	133	▼
Estonia	530.9	2.7	93	▲	*Chile*	439.6	5.1	103	▼
Netherlands	525.6	3.3	106	▲	*Uruguay*	429.0	3.1	107	▼
Switzerland	518.8	3.4	111	▲	*Serbia*	424.9	3.7	100	▼
Slovenia	516.1	1.3	100	▲	*Thailand*	423.1	2.6	91	▼
Belgium	516.0	3.0	113	▲	Turkey	417.2	4.3	97	▼
Germany	515.4	4.6	115	▲	*Bulgaria*	416.7	7.5	127	▼
United Kingdom	513.6	2.5	117	▲	*Romania*	407.5	6.0	104	▼
Macao-China	511.5	1.2	84	▲	*Montenegro*	406.6	1.3	93	▼
France	511.0	3.9	114	▲	*Jordan*	404.5	3.3	101	▼
Ireland	505.9	3.4	102	▲	Mexico	402.2	3.1	94	▼
Austria	504.8	4.7	116	o	*Indonesia*	385.7	7.3	83	▼
Czech Republic	500.5	4.1	113	o	*Argentina*	385.4	7.0	117	▼
Hungary	497.1	3.4	102	o	*Colombia*	383.2	3.9	91	▼
Sweden	496.1	2.6	106	o	*Tunisia*	381.9	3.7	95	▼
Poland	493.7	2.7	98	▼	*Brazil*	378.1	3.6	105	▼
Luxembourg	491.8	1.1	113	▼	*Azerbaijan*	344.3	4.0	77	▼
Iceland	491.0	1.7	111	▼	*Qatar*	323.9	1.2	103	▼
Latvia	490.7	3.4	92	▼	*Kyrgyzstan*	288.0	3.8	105	▼
Croatia	490.3	3.0	96	▼	OECD average	499.2	0.6	108	
Denmark	488.6	3.6	107	▼	OECD total	491.7	1.5	117	
United States	488.5	5.0	116	▼					

(black)	Mean significantly higher than Ireland	▲	Above OECD average
(white)	Mean not significantly different from Ireland	o	At OECD average
(grey)	Mean significantly lower than Ireland	▼	Below OECD average

OECD countries are in regular font; partner countries are in italics.

Table 3.8 shows scores at key percentile indicators on the *using scientific evidence* scale. The gap of 335 points between Irish students at the 5th and 95th percentile is smaller than the OECD average of 352 points. Of countries shown in Table 3.8, the smallest spreads of achievement between the 5th and 95th percentiles are found in Finland (316 points) and Poland (322), while the largest spread is found in Northern Ireland (405 points).

Considering students at the 5th percentile, Ireland's mean score of 331 at this key marker is 15 points higher than the OECD average of 316. Thus, Ireland's lower-achieving students are performing better than the corresponding OECD average. Ireland has the 7th highest score at this marker amongst OECD countries. As with the other science competency subscales, students in Finland obtained the highest score (overall and at the 5th percentile). Finnish students' score of 406 at the 5th percentile is almost three-quarters of a standard deviation higher than the score obtained by Irish students at that marker. Irish students at the 95th percentile obtained a score that differed from the OECD average at this marker by only 2 points. Thus, Ireland's slightly better than average overall performance on *using scientific evidence* can be attributed to a relatively good performance by low-achieving students, rather than to a group of exceptionally high-achieving students.

The spread of achievement in Ireland on *using scientific evidence* can be contrasted with the spread in Northern Ireland. Although both mean scores were very similar (506 versus 508, respectively), Northern Irish students at the 5th percentile obtained a score that is 34 points lower than that obtained by students in the Republic. At the other extreme (the 95th percentile), the score obtained by students in Northern Ireland was 36 points higher than that of students in the Republic. Thus, the range of achievement is more truncated in the Republic than in Northern Ireland, with fewer very low- and very high- achieving students.

Table 3.8: Percentage of students at key percentile markers on the using scientific evidence scale in Ireland, the five highest performing countries, and selected comparison countries

	Mean	5th		10th		25th		75th		90th		95th	
		Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Finland	567.4	406	5.4	442	4.0	504	2.9	633	2.7	690	2.9	722	3.9
Japan	544.3	340	8.6	388	7.9	468	5.9	627	3.6	685	3.4	719	4.8
Hong Kong-China	542.4	367	6.0	408	4.7	479	4.4	613	3.1	663	3.2	691	3.3
Canada	541.5	370	4.3	408	4.3	477	2.9	612	2.2	664	2.5	695	3.1
Korea	538.5	359	9.1	402	7.6	473	5.4	611	4.1	664	4.3	694	5.0
New Zealand	536.8	331	7.1	377	5.2	453	4.4	624	3.4	687	4.5	725	4.9
Scotland	521.3	335	10.1	375	5.6	443	5.0	601	4.4	666	5.3	705	5.2
Germany	515.4	317	11.2	361	8.1	440	6.8	597	3.9	658	4.2	691	4.4
England	513.6	315	7.3	360	5.0	434	4.2	598	3.6	662	3.7	699	4.1
N. Ireland	508.3	297	9.1	342	6.7	420	5.3	599	4.7	665	6.0	702	6.4
Ireland	505.9	331	5.4	370	5.0	437	4.5	579	3.1	635	3.8	666	4.5
Wales	504.3	321	7.1	360	7.0	426	5.4	585	4.4	647	4.7	684	5.6
OECD	499.2	316	1.3	357	1.1	427	0.8	576	0.7	635	0.7	668	0.8
Poland	493.7	330	4.7	365	3.7	425	3.4	563	3.5	621	3.5	652	4.0
Denmark	488.6	310	6.6	349	4.8	416	4.3	564	3.9	624	4.6	658	5.3
US	488.5	296	10.1	335	8.8	405	7.0	573	5.1	640	5.2	677	5.9

Science Proficiency Levels

As well as mean scores and scores at key percentile markers, PISA describes *proficiency levels* and provides information on the percentages of students at each level. Proficiency levels allow a description of the competencies that students obtaining scores at varying score intervals can demonstrate. There are six proficiency levels, with Level 6 representing the highest (i.e., the most complex scientific skills). As explained in the initial PISA 2006 report 'The grouping into proficiency levels was undertaken on the basis of substantive considerations relating to the nature of the underlying competencies' (OECD, 2007b, p. 42). There is also a 'Below Level 1' category for students who did not demonstrate the competencies required for the simplest PISA science tasks. Inset 3.2 provides some background into how proficiency levels are developed and how they should be interpreted.

Inset 3.2: What are Proficiency Levels?

Each student is assigned to the highest level at which he or she would be expected to answer correctly the majority of assessment questions. For example, in an assessment composed of questions spread uniformly across Level 3, all students assigned to that level would expect to get at least 50% of questions correct. However, the score points for students would vary within a level. For example, a student at the bottom of the level would be expected to get just above 50% of the questions correct. A student near the top of the level would get a higher percentage of questions correct[1].

The six proficiency levels present a comprehensive range of achievement that PISA defines as *scientific literacy*. Level 2 is defined as the baseline proficiency level. This level does not establish a threshold for scientific illiteracy. Rather, the baseline level of proficiency defines the level of achievement on the PISA scale at which students begin to demonstrate the science competencies that will enable them to participate effectively and productively in life situations related to science and technology and in future education. To reach Level 2, for example, requires competencies such as identifying key features of a scientific investigation, recalling single scientific concepts and information relating to a situation, and using results of a scientific experiment represented in a data table as they support a personal decision. In contrast, students at Level 1 often confuse key features of an investigation, apply incorrect scientific information, and mix personal beliefs with scientific facts in support of a decision. Table 3.9 provides further details about what students can typically do and differentiates student achievement at Levels 1 and 2, thus showing what is needed to reach the critical baseline for PISA competencies.

Beyond the interpretation of performance differences, the proficiency scales can be used to identify skills and abilities that will contribute to higher levels of student achievement. For example, being able to select and integrate knowledge from different disciplines and using that knowledge to develop more detailed communications distinguishes students at Level 4 from those at Level 3, where students can only 'interpret and use' knowledge from different disciplines.

1. Students at the bottom of a level have a 0.62 chance of correctly answering the questions at the bottom of that level and a 0.42 chance of answering questions at the top of the level. Students at the top of a level have a 0.62 chance of correctly answering the most difficult questions at that level, and a 0.78 chance of answering the easiest questions.

Adapted from OECD (2007b) pp. 42-44

Overall Science Scale

Table 3.9 shows the types of competencies that exemplify each proficiency level on the overall science scale, the percentages of students (Ireland and the OECD average) at each level, and the score ranges for each level. For example, students who obtained a score that fell between 633.3 and 709.9 were classified as reaching proficiency level 5. The table also identifies examples of released PISA items that are illustrative of the skills required at each proficiency level. A sample of released items is presented in

Appendix A, while all can be accessed at *www.erc.ie/pisa*. Each test item has an associated item difficulty score (similar to the achievement scales, with a mean close to 500 and a standard deviation of 100). Some items are labelled 'full credit' or 'partial credit', and are assigned different item difficulty scores on this basis. For example, Question 5 from the unit *Acid Rain* is shown as an item that is illustrative of performance at Level 6, but only where the student response has been assigned a full credit. If a student was assigned a partial credit for Question 5 (e.g., while largely correct, the answer may not have been as complex or complete as required), the item difficulty score drops from 717 to 513, and the response is illustrative of performance at proficiency level 3.

At 1.1%, the percentage of Irish students classified as at proficiency level 6 was similar to the OECD average of 1.3%. Students at this level can engage in the most complex scientific tasks assessed by PISA. They can *consistently* identify and use scientific knowledge in a variety of situations, and link information from different sources to produce evidence-based decisions. If Levels 5 and 6 are considered together, the percentage of Irish students achieving these high proficiency levels is very similar to the OECD average (approximately 9% in both cases). *Acid Rain* Question 5 is an example of an item that students at Level 6 might be expected to answer correctly. This item requires students to demonstrate competency in *identifying scientific issues,* while displaying knowledge of *scientific enquiry*.

The question detailed how students performed an experiment on the effects of vinegar on marble chips (modelling the effect of acid rain) and asked why the students also placed some chips in distilled water. For a full credit response, students needed to show understanding that vinegar is needed as a reactant, that the reaction will not occur in water, and to demonstrate an understanding of a control in scientific experiments. Students who understood that a comparison was being made, but did not demonstrate understanding of the purpose of the comparison, were assigned a partial credit. In Ireland, 23.0% of students obtained a full credit on this item, (compared to an OECD average of 14.0%) while 45.4% obtained a partial credit (OECD average, 43.0%).

Relatively more Irish students (84.5%) reach the baseline proficiency level of 2 than the average across OECD countries (80.7%). Examining the distribution of students across the science proficiency levels, it appears that Ireland's slightly above average overall performance can be attributed to small percentages of students at the lowest proficiency levels rather than to large percentages at the highest levels. Another item from the *Acid Rain* unit (Question 3) demonstrates the performance expected of students reaching Level 2. Students are asked to draw a conclusion about the effects of vinegar on marble using several pieces of information provided:

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

Using the reasonably obvious cues provided, the student must indicate if the weight of the chip will increase, decrease, or remain the same. In Ireland, 68.4% of students correctly answered this question, compared to an OECD average of 66.7%.

Table 3.9: Proficiency levels on the PISA 2006 overall science scale, examples of test items and associated item difficulties at each level, and percentages of students achieving each level (Ireland and OECD average)

Level & score range	Sample items & difficulty	What students can typically do	IRL %	IRL SE	OECD %	OECD SE
6 (709.9 and above)	Acid rain Q5 (Full credit: 717) Greenhouse Q5 (709)	Students can consistently identify, explain and apply scientific knowledge and *knowledge about science* in a variety of complex life situations. They can link different information sources and explanations and use evidence from those sources to justify decisions. They clearly and consistently demonstrate advanced scientific thinking and reasoning, and they demonstrate willingness to use their scientific understanding in support of solutions to unfamiliar scientific and technological situations. Students at this level can use scientific knowledge and develop arguments in support of recommendations and decisions that centre on personal, social or global situations.	1.1	0.19	1.3	0.04
5 (709.9 – 633.3)	Greenhouse Q4 (Full credit: 659)	Students can identify the scientific components of many complex life situations, apply both scientific concepts and *knowledge about science* to these situations, and can compare, select and evaluate appropriate scientific evidence for responding to life situations. Students at this level can use well-developed inquiry abilities, link knowledge appropriately and bring critical insights to situations. They can construct explanations based on evidence and arguments based on their critical analysis.	8.3	0.62	7.7	0.10
4 (633.3 – 558.7)	Sunscreens Q5 (Full credit: 629) Greenhouse Q4 (Partial credit: 568)	Students can work effectively with situations and issues that may involve explicit phenomena requiring them to make inferences about the role of science or technology. They can select and integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations. Students at this level can reflect on their actions and they can communicate decisions using scientific knowledge and evidence.	21.4	0.87	20.3	0.16
3 (558.7 – 484.1)	Acid rain Q5 (Partial credit: 513) Grand Canyon Q7 (485)	Students can identify clearly described scientific issues in a range of contexts. They can select facts and knowledge to explain phenomena and apply simple models or inquiry strategies. Students at this level can interpret and use scientific concepts from different disciplines and can apply them directly. They can develop short statements using facts and make decisions based on scientific knowledge.	29.7	0.98	27.4	0.17
2 (484.1 – 409.5)	Acid rain Q3 (460) Grand Canyon Q5 (411)	Students have adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving.	24.0	0.91	24.0	0.17
1 (409.5 – 334.9)	Clothes Q2 (399)	At Level 1, students have such a limited scientific knowledge that it can only be applied to a few, familiar situations. They can present scientific explanations that are obvious and that follow explicitly from given evidence.	12.0	0.82	14.1	0.15
< 1 (334.9 and below)		Students below Level 1 have a less than 50% chance of correctly answering Level 1 questions. Scientific literacy is not assessed by PISA.	3.5	0.47	5.2	0.11

Adapted from OECD (2007b) Figure 2.8, p.43

Table 3.10 shows the percentages of students at each science proficiency level in key comparison countries. While, as noted, Ireland has roughly the same percentage of students at Levels 5 or 6 as the OECD average, this is considerably smaller than the 21% of students in Finland who scored at Level 5 or 6. Finland also has relatively few students (4%) failing to reach the baseline Level 2. Thus, Finland can be characterised as a country with a large percentage of students demonstrating the highest levels of scientific skills and thinking, and with very few students unable to function as scientifically literate members of society. In contrast, almost one-quarter of students in the US fail to demonstrate baseline proficiency in scientific literacy.

Table 3.10: Percentage of students at each overall science proficiency level in Ireland, the five highest performing countries, and selected comparison countries

	Below Level 1		Level 1		Level 2		Level 3		Level 4		Level 5		Level 6	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Finland	0.5	0.13	3.6	0.45	13.6	0.68	29.1	1.07	32.2	0.89	17.0	0.72	3.9	0.35
Hong Kong-China	1.7	0.36	7.0	0.68	16.9	0.81	28.7	0.95	29.7	0.95	13.9	0.80	2.1	0.30
Canada	2.2	0.27	7.8	0.47	19.1	0.64	28.8	0.58	27.7	0.65	12.0	0.52	2.4	0.25
Chinese Taipei	1.9	0.29	9.7	0.82	18.6	0.86	27.3	0.80	27.9	1.03	12.9	0.77	1.7	0.24
Estonia	1.0	0.23	6.7	0.57	21.0	0.88	33.7	0.96	26.2	0.94	10.1	0.71	1.4	0.27
New Zealand	4.0	0.43	9.7	0.58	19.7	0.80	25.1	0.71	23.9	0.81	13.6	0.74	4.0	0.37
Germany	4.1	0.68	11.3	0.96	21.4	1.06	27.9	1.08	23.6	0.95	10.0	0.62	1.8	0.24
England	4.9	0.57	11.8	0.72	21.5	0.85	25.7	0.81	22.1	0.74	11.0	0.62	3.0	0.35
Scotland	3.6	0.64	11.0	0.98	24.1	1.23	27.9	1.11	20.7	1.09	10.1	0.94	2.4	0.51
Ireland	3.5	0.47	12.0	0.82	24.0	0.91	29.7	0.98	21.4	0.87	8.3	0.62	1.1	0.19
N. Ireland	6.6	0.75	13.7	0.74	20.6	1.05	24.3	1.46	20.9	1.38	11.2	1.07	2.7	0.43
Wales	4.5	0.68	13.6	0.81	24.3	1.04	26.9	0.98	19.8	0.99	9.0	0.84	1.9	0.43
OECD avg.	5.2	0.11	14.1	0.15	24.0	0.17	27.4	0.17	20.3	0.16	7.7	0.10	1.3	0.04
Poland	3.2	0.36	13.8	0.63	27.5	0.94	29.4	1.02	19.3	0.80	6.1	0.44	0.7	0.14
Denmark	4.3	0.64	14.1	0.75	26.0	1.07	29.3	1.04	19.5	0.91	6.1	0.66	0.7	0.18
US	7.6	0.94	16.8	0.88	24.2	0.94	24.0	0.79	18.3	0.97	7.5	0.62	1.5	0.25

Identifying Scientific Issues

Questions relating to *identifying scientific issues* composed approximately 23% of the total science item pool. As outlined in Chapter 1, the key skills for this competency are recognising issues that can be investigated scientifically, identifying key search words, and recognising the key features of a scientific investigation. Table 3.11 shows the percentages of students (Ireland and OECD average) classified at each proficiency level for *identifying scientific issues*, and provides a broad description of the general proficiencies demonstrated by students at each level, as well as outlining specific tasks that students should be able to perform.

As this was the science competency on which Irish students obtained the highest mean score (516), it is unsurprising that Ireland had a slightly higher percentage of students (11%) scoring at Levels 5 or 6 than the OECD average (8%). In Ireland also, the percentage of students (14%) categorised as below Level 2 was less than the average across OECD countries (19%).

Table 3.11: Proficiency levels on the PISA 2006 identifying scientific issues scale, illustrative tasks, and percentages of students achieving each level (Ireland and OECD average)

Level & score range	General proficiencies	Tasks a student should be able to do	IRL %	IRL SE	OECD %	OECD SE
6 (709.9 and above)	Can demonstrate an ability to understand and articulate the complex modelling inherent in the design of an investigation.	• Articulate the aspects of a given experimental design that meet the intent of the scientific question being addressed. • Design an investigation to adequately meet the demands of a specific scientific question. • Identify variables that need to be controlled in an investigation and articulate methods to achieve that control	1.8	0.33	1.3	0.04
5 (633.3–709.9)	Can understand the essential elements of a scientific investigation, determine if scientific methods can be applied in a variety of complex, and often abstract contexts. Alternatively, by analysing a given experiment can identify the question being investigated and explain how the methodology relates to that question.	• Identify the variables to be changed and measured in an investigation of a wide variety of contexts. • Understand the need to control all variables extraneous to an investigation but impinging on it. • Ask a scientific question relevant to a given issue.	9.2	0.66	7.1	0.11
4 (558.7–633.3)	Can identify the change and measured variables in an investigation and at least one variable that is being controlled. Can suggest appropriate ways of controlling that variable. The question being investigated in straightforward investigations can be articulated.	• Distinguish the control against which experimental results are to be compared. • Design investigations in which the elements involve straightforward relationships and lack appreciable abstractness. • Show an awareness of the effects of uncontrolled variables and attempt to take this into account in investigations.	22.9	0.87	20.0	0.16
3 (484.1–558.7)	Are able to make judgements about whether an issue is open to scientific measurement and, consequently, to scientific investigation. Given a description of an investigation can identify the change and measured variables.	• Identify the quantities able to be scientifically measured in an investigation. • Distinguish between the change and measured variables in simple experiments. • Recognise when comparisons are being made between two tests without being able to articulate the purpose of a control.	29.2	0.84	28.3	0.18
2 (409.5–484.1)	Can determine if scientific measurement can be applied to a given variable in an investigation. Can recognise the variable being manipulated (changed) by the investigator. Can appreciate the relationship between a simple model and the phenomenon it is modelling. In researching topics students can select appropriate key words for a search.	• Identify a relevant feature being modelled in an investigation. • Show an understanding of what can and cannot be measured by scientific instruments. • Select the most appropriate stated aims for an experiment from a given selection. • Recognise what is being changed (the cause) in an experiment. • Select a best set of Internet search words on a topic from several given sets.	23.2	1.08	24.6	0.17
1 (334.9–409.5)	Can suggest appropriate sources of information on scientific topics. Can identify a quantity that is undergoing variation in an experiment. In specific contexts can recognise whether that variable can be measured using familiar measuring tools or not.	• Select some appropriate sources from a given number of sources of potential information on a scientific topic. • Identify a quantity that is undergoing change, given a specific but simple scenario. • Recognise when a device can be used to measure a variable (within the scope of the student's familiarity with measuring devices).	10.7	0.79	13.5	0.14
<1 (below 334.9)		Scientific literacy is not assessed by PISA.	3.0	0.45	5.2	0.11

Adapted from OECD (2007b) Figure 2.20, p. 77-78.

Explaining Phenomena Scientifically

Almost half (48%) of science items assessed the competency *explaining phenomena scientifically*. The competency has 'a combined emphasis on major concepts fundamental to science disciplines complemented with facts and information associated with basic concepts' (OECD, 2007b, p.86). As described in Chapter 1, the key skills associated with the competency are applying *knowledge of science*, describing or interpreting phenomena scientifically and predicting changes, and identifying appropriate descriptions and predictions. The mean score of Irish students on *explaining phenomena scientifically* (505) was quite similar to the OECD average of 500. This is reflected in identical percentages (1.8%) classified as Level 6 and almost identical percentages classified as Levels 5 or 6 (roughly 10% of students in Ireland and on average in OECD countries) (Table 3.12). A slightly smaller percentage of students in Ireland (17.1%) than was the average in OECD countries (19.6%) performed below the baseline proficiency level of 2.

Table 3.12: Proficiency levels on the PISA 2006 explaining phenomena scientifically scale, illustrative tasks, and percentages of students achieving each level (Ireland and OECD average)

Level & score range	General proficiencies	Tasks a student should be able to do	IRL		OECD	
			%	SE	%	SE
6 (709.9 and above)	Can draw on a range of abstract scientific knowledge and concepts and the relationships between the developing explanations of processes within systems.	• Demonstrate an understanding of a variety of complex, abstract physical, biological or environmental systems. • In explaining processes, articulate the relationships between a number of discrete elements or concepts.	1.8	0.32	1.8	0.05
5 (633.3 – 709.9)	Can draw on knowledge of two or three scientific concepts and identify the relationship between them in developing an explanation of a contextual phenomenon.	• Take a scenario, identify its major component features, and use the relationships between these features in providing an explanation of a phenomenon. • Synthesise central scientific ideas in a given context in developing an explanation for, or a prediction of, an outcome.	8.5	0.70	8.0	0.11
4 (558.7 – 633.3)	Have an understanding of scientific ideas, including scientific models, with a significant level of abstraction. They can apply a general, scientific concept containing such ideas in the development of an explanation of a phenomenon.	• Understand a number of abstract scientific models and select an appropriate one from which to draw inferences in explaining a phenomenon in a specific context. • Link two or more pieces of specific knowledge in an explanation	19.9	0.90	19.7	0.15
3 (484.1 – 558.7)	Can apply concrete/tangible scientific ideas/concepts in the development of an explanation of a phenomenon. When developing an explanation, cause and effect relationships are recognised and simple, explicit scientific models may be drawn upon.	• Understand the central feature(s) of a scientific system and, in concrete terms, predict outcomes from changes in that system. • In a simple and clearly defined context, recall several relevant, tangible facts and apply these in developing an explanation of the phenomenon.	28.0	1.16	27.0	0.17
2 (409.5 – 484.1)	Can recall an appropriate, tangible, scientific fact applicable in a simple and straightforward context and can use it to explain or predict an outcome.	• Given a specific outcome in a simple context, indicate, in a number of cases and with appropriate cues the scientific fact or process that has caused that outcome. • Recall specific scientific facts with general currency in the public domain.	24.6	1.04	24.0	0.17
1 (334.9 – 409.5)	Can recognise simple cause and effect relationships given relevant cues. The knowledge drawn upon is a singular scientific fact that is drawn from experience or has widespread popular currency.	• Choose a suitable response from among several responses, given the context is a simple one and that recall of a single scientific fact is involved. • Given sufficient cues, recognise simple cause and effect relationships.	12.6	0.74	14.2	0.15
<1 (below 334.9)		Scientific literacy is not assessed by PISA.	4.5	0.51	5.4	0.11

Adapted from OECD (2007b) Figure 2.24, p. 86-87.

Using Scientific Evidence

Thirty percent of science items assessed the competency *using scientific evidence*. The main skills associated with the competency – shown in Table 3.13 – are interpreting scientific evidence, drawing conclusions (and identifying the assumptions behind conclusions) and reflecting on the societal implications of science and technological developments. The mean score of Irish students on *using scientific evidence* (506) was slightly above the OECD average of 499. Despite this, the percentage of Irish students performing at the Levels 5 or 6 (10.4%) is marginally lower than the average across OECD countries (11.8%). However, Ireland also had a smaller percentage (17.9%) than the OECD average performing below the baseline proficiency level of 2 (22.0%).

A Comparison Across Scales

If Irish performance on each of the three competencies, and science overall, is considered, it can be seen that the percentage of Irish students performing at the highest proficiency levels (5 or 6) was reasonably similar to the OECD average, while the percentages failing to reach the baseline proficiency level of 2 were smaller in Ireland than the corresponding OECD average. Thus, a minority of Irish 15-year-olds demonstrated high levels of proficiency in the components of scientific literacy. A significant minority also failed to demonstrate sufficient scientific literacy to 'enable them to participate effectively and productively in life situations related to science and technology' (OECD, 2007b, p.44).

Table 3.13: Proficiency levels on the PISA 2006 using scientific evidence scale, illustrative tasks, and percentages of students achieving each level (Ireland and OECD average)

Level & score range	General proficiencies	Tasks a student should be able to do	IRL %	IRL SE	OECD %	OECD SE
6 (709.9 and above)	Can use supporting evidence to compare and differentiate among competing explanations. They can formulate arguments by synthesizing evidence from multiple sources	• Recognise that alternative hypotheses can be formed from the same set of evidence. • Test competing hypotheses against evidence. • Construct a logical argument for an hypothesis by using multiple data sources.	1.6	0.25	2.4	0.06
5 (709.9 – 633.3)	Can interpret data from related datasets presented in various formats. They can identify and explain differences and similarities in the datasets and draw conclusions based on the combined evidence presented in those datasets	• Compare and discuss the characteristics of different datasets graphed on the one set of axes. • Recognise and discuss relationships between datasets in which the measured variable differs. • Based on an analysis of the sufficiency of the data, make judgements about the validity of conclusions.	8.8	0.73	9.4	0.12
4 (633.3 – 558.7)	Can interpret a dataset expressed in a number of formats, such as tabular, graphic and diagrammatic, by summarizing the data and explaining relevant patterns. They can use the data to draw relevant conclusions. Students can also determine whether the data supports assertions about a phenomenon.	• Locate and compare relevant parts of graphs. • Understand how to use a control in analysing the results of an investigation and developing a conclusion. • Interpret a table that contains two measured variables and suggest credible relationships between those variables. • Identify the characteristics of a straightforward technical device by reference to diagrammatic representations and form conclusions about its method of operation.	21.5	1.12	19.8	0.16
3 (558.7 – 484.1)	Can select a piece of relevant information from data in answering a question or in providing support for or against a given conclusion. They can draw a conclusion from an uncomplicated or simple pattern in a dataset. Students can also determine, in simple cases, if enough information is present to support a given conclusion.	• Given a specific question, locate relevant scientific information in a body of text. • Given specific evidence/data, choose between appropriate and inappropriate conclusions. • Apply a simple set of criteria in a given context in order to draw a conclusion or make a prediction about an outcome. • Given a set of functions, determine if they are applicable to a specific machine.	27.6	1.02	24.7	0.17
2 (484.1 – 409.5)	Can recognise the general features of a graph if given appropriate cues and can point to an obvious feature in a graph or simple table in support of a given statement. They are able to recognise if a set of given characteristics apply to the function of everyday artefacts in making choices about their use.	• Compare two columns in a simple table of measurements and indicate differences. • State a trend in a set of measurements or simple line or bar graph. • Given a common artefact can determine some characteristics or properties pertaining to the artefact from among a list of properties.	22.6	0.84	21.7	0.16
1 (409.5 – 334.9)	Can extract information from a fact sheet or diagram pertinent to a common context. They can extract information from bar graphs where the requirement is simple comparisons of bar heights. In common, experienced contexts, can attribute an effect to a cause.	• In response to a specific question pertaining to a bar graph, make comparisons of the height of bars and give meaning to the difference observed. • Given variation in a natural phenomenon can, in some cases, indicate an appropriate cause	12.5	0.72	14.1	0.15
<1 (334.9 and below)		Scientific literacy is not assessed by PISA.	5.4	0.58	7.9	0.14

Adapted from OECD (2007b) Figure 2.24, p. 101-102.

Knowledge *of* and *About* Science

As outlined in Chapter 1, PISA scientific literacy refers to both *knowledge of science* and *knowledge about science*. One scale was developed to assess *knowledge about science*, while three scales were developed to assess *knowledge of science* (*knowledge of living systems*, *Earth and space systems*, and *physical systems)*. In this section, we compare the performance of Irish students on each of these scales with OECD-level performance, and comment on differences in Irish performance between scales. Table 3.14 shows the means of the top five performing countries on each scale, and the set of comparison countries. Unlike the scales for overall science performance and for scientific competencies, no data were made publicly available for what the OECD refer to as 'non-adjudicated sub-national regions', a category that includes Northern Ireland, England and Wales . Thus, we compare Irish performance with the UK as a whole, rather than with its constituent parts.

On two scales – *knowledge about science* and *Earth and space systems* – Irish students obtained a mean that is significantly above the OECD average, while on two – *knowledge of living systems* and *physical systems* – the Irish mean was above the OECD average, but not significantly so (Table 3.14). On each of the four scales, Finnish students obtained the highest mean score, while students in Hong Kong-China obtained the second highest score on three of the four scales. The gap between Irish and Finnish students was most pronounced for *knowledge of living systems,* for which the mean obtained by students in Finland exceeded the Irish mean by 68 points.

Table 3.14: Mean achievement scores for the knowledge of and about science scales, in Ireland, the five highest performing countries, and selected comparison countries

Knowledge about science			Earth and space systems			Living systems			Physical systems		
	Mean	SE		%	SE		%	SE		%	SE
Finland	557.7	1.7	Finland	554.3	1.8	Finland	573.8	1.8	Finland	559.7	1.7
Hong Kong-C	541.6	2.5	*Estonia*	540.4	2.4	*Hong Kong-C*	557.7	2.3	*Hong Kong-C*	545.6	2.4
N. Zealand	539.1	2.5	Canada	540.3	1.8	*Ch. Taipei*	549.4	3.3	*Ch. Taipei*	545.5	3.1
Canada	537.3	2.0	*Slovenia*	533.5	1.7	*Estonia*	539.8	2.4	*Estonia*	535.	2.0
Australia	533.4	1.9	Korea	533.0	3.0	Canada	530.5	2.1	Czech R.	534.0	3.3
Japan	531.6	3.2	N. Zealand	529.5	2.4	N. Zealand	528.1	2.7	Germany	516.1	3.1
UK	516.5	1.9	Germany	510.3	3.6	UK	525.4	2.2	N. Zealand	515.7	2.4
Ireland	512.7	2.7	**Ireland**	508.1	2.8	Germany	523.9	3.0	UK	508.4	2.0
Germany	511.7	3.1	UK	504.6	1.9	Poland	509.1	2.1	**Ireland**	504.5	2.6
OECD	499.9	0.5	US	504.0	2.8	**Ireland**	505.6	3.0	Denmark	502.5	2.8
Denmark	492.7	2.6	Poland	501.3	2.4	Denmark	504.8	2.9	OECD	500.0	0.5
US	492.2	3.7	OECD	499.5	0.5	OECD	501.8	0.5	Poland	497.1	2.1
Poland	490.6	2.1	Denmark	486.9	2.8	US	486.8	4.1	US	485.2	3.8

Mean significantly higher than Ireland

Mean not significantly different from Ireland

Mean significantly lower than Ireland

OECD countries are in regular font; partner countries are in italics.

The mean scores obtained by Irish students for *knowledge about science* and *Earth and space systems* were very similar to the German and UK means on these scales, differing by only a few points. However, on *knowledge of living systems*, the German and UK means exceeded the Irish mean by 18 and 20 points, respectively, while the German mean for *knowledge of physical systems* exceeded the Irish mean by 12 points. While students in Ireland significantly outperformed students in Denmark (by quite a large margin) on *knowledge about science* and *Earth and space systems,* students in both countries obtained very similar mean scores on *knowledge of living systems* and *knowledge of physical systems.*

Ireland ranked 10th of OECD countries on *Earth and space systems*, 11th of OECD countries on *knowledge about science,* 15th on *knowledge of living systems,* and 16th on *physical systems. Knowledge of living systems* was the only knowledge subscale where the spread of achievement between the 5th and 95th percentiles in Ireland (340) was larger than the average spread across OECD countries (328).

Performance Across Science Scales

As well as comparing Ireland's performance with other countries on a particular scale, we can compare how Ireland (and other countries) performed on one scale relative to another. Cluster analyses conducted by the OECD identified groups of countries with similar strengths and weaknesses on subscales. These analyses revealed that Ireland is one of a group of nine countries in which students showed a relative strength in *identifying scientific issues*. Other OECD countries in the cluster were The Netherlands, Iceland, US, Portugal, and Mexico. In contrast, although both high-performing countries overall, Hong Kong-China and Estonia were characterised as showing a (relative) weakness in *identifying scientific issues*.

The performances of Irish students on the three science competencies are highly correlated. The strongest correlation is between *explaining phenomena scientifically* and *identifying scientific issues* (.91), followed by *explaining phenomena scientifically* and *using scientific evidence* (.90), and *identifying scientific issues* and *using scientific evidence* (also .90).

Ireland's mean scores for the three *knowledge of science* domains are quite similar and performances on the three domains are strongly intercorrelated (correlations range from .87 for *Earth and space systems* and *living systems* to .92 between *living systems* and *physical systems*). Nevertheless, with the exception of consistently high-performing countries such as Finland and Japan, we find differences in performance between countries across these domains. For example, although Korea ranked third of OECD countries on *Earth and space systems*, they ranked only 20th on *knowledge of living systems.*

The OECD also reported an overall *knowledge of science* scale, which is merely an average of the three *knowledge of science* scales. Although it should only be regarded as a rough summary estimate, as it has not been properly scaled, it is useful to compare country differences in overall means on *knowledge of* and *about science*. In Ireland, and on average across OECD countries, there is a small gap between mean scores on *knowledge about science* and *knowledge of science.* However, in some countries, large differences are found. For example, in the neighbouring countries of Hungary and the Czech and Slovak Republics, students perform much better on *knowledge of science* than on *knowledge about science* (a minimum 24 points difference). This has been attributed to 'similar traditions in science education, in which science is taught with a focus on the accumulation and reproduction of theoretical knowledge in scientific disciplines, with much less emphasis on the nature of scientific work and scientific thinking.' (OECD, 2007b, p. 71). In contrast, in France there is a 29-point gap in favour of *knowledge about science*.

Gender Differences on Scientific Literacy

In this section, we describe gender differences in mean scores on each science scale. This is followed by a description of the percentages of males and females at various proficiency levels.

Gender Differences in Mean Scores on Science Scales

In Ireland, the mean score on the overall science scale obtained by females is almost identical to that obtained by males and the difference is not significant (Table 3.15). Across the OECD as a whole, there were small (but significant) gender differences in performance on the overall science scale, with males outperforming females by 2.2 points. However, the nature of gender differences in science performance varied across countries. While significant differences favouring males were found in six OECD countries (the largest gap being a 10-point advantage for males in the UK), significant differences (of roughly 12 points) favouring females were found in two OECD countries (Greece and Turkey).

Table 3.15: Gender differences among Irish students on science subscales, with comparative OECD data

Scale type		IRL Males		IRL Females		Gender scoring sig. higher	
		Mean	SE	Mean	SE	IRL	OECD
Overall	Overall science scale	508.1	4.3	508.5	3.3	–	Males
Competency	Identify scientific issues	507.7	4.4	523.9	3.5	Females	Females
	Explain phen. scientifically	510.2	4.4	500.9	3.5	Males	Males
	Use scientific evidence	502.5	4.8	509.3	3.5	–	Females
Knowledge …	about science	508.2	3.7	517.2	2.8	Females	Females
	of Earth & space systems	515.2	3.9	501.2	3.2	Males	Males
	of living systems	504.6	4.0	506.5	3.4	–	Males
	of physical systems	516.0	3.7	493.2	3.0	Males	Males

Although the performance of Irish students revealed no overall significant gender difference, some of the subscales show quite large differences. Females significantly outperformed males on *identifying scientific issues* (by 16 points), and on *knowledge about science* (by 9 points). Similar gender differences are found in the OECD average scores. Males in Ireland significantly outperformed females on *explaining phenomena scientifically*, *knowledge of physical systems* and *Earth and space systems*, with the largest difference (23 points) on *physical systems*. Again, similar gender differences are found in the OECD average scores.

Gender Differences at Proficiency Levels

Although males and females in Ireland obtained an almost identical mean score, there are some differences in the distribution of achievement on the overall science scale (Table 3.16)[2]. There were marginally more males than females at the highest and lowest proficiency levels, and marginally more females in the middle proficiency levels (Levels 2, 3, and 4).

The percentages of males and females in Ireland that were classified at the highest proficiency levels of 5 or 6 (10.3% of males and 8.5% of females) was similar to the average in OECD countries (10.0% of males and 7.9% of females). Compared to the OECD country average, proportionally fewer Irish males and females were classified as not reaching the baseline proficiency level of 2, but the direction of the gender difference remains the same, with more males failing to reach Level 2. For example, in Ireland 16.6% of males and 14.5% of females were classified as not demonstrating baseline science proficiency, compared to the OECD average of 19.7% of males and 18.7% of females.

Table 3.16: Percentages of males and females achieving each proficiency level on the overall science scale (Ireland and OECD average)

	Ireland				OECD			
	Male		Female		Male		Female	
	%	SE	%	SE	%	SE	%	SE
Level 6	1.4	0.31	0.9	0.29	1.5	0.06	1.0	0.05
Level 5	8.9	0.92	7.6	0.75	8.5	0.15	6.9	0.13
Level 4	21.1	1.10	21.6	1.23	20.5	0.21	20.2	0.21
Level 3	28.8	1.22	30.6	1.58	26.4	0.22	28.5	0.23
Level 2	23.2	1.24	24.8	1.68	23.4	0.23	24.7	0.23
Level 1	12.5	1.28	11.5	0.91	14.1	0.19	14.0	0.19
< Level 1	4.1	0.68	3.0	0.51	5.6	0.15	4.7	0.13

Trends in Performance on Scientific Literacy

PISA scales are 'anchored' in the cycle in which they were the major domain. In 2000, the major domain was reading, while in 2003 it was mathematics. Consequently, the OECD 'anchor' mean for reading was set at 500 based on the 2000 results, and the means in 2003 and 2006 fluctuated around that anchor. Anchoring the scale allows examination of how overall performance varies from one cycle to the next, but it also means that the scales are not anchored until they are a major domain. PISA 2006 is the first time that science was assessed as a major PISA domain, meaning that 2006 is the anchor year and that comprehensive data on trends in science performance are not available.

[2] Full information on proficiency levels by gender for each of the three main science competencies, and information on performance by gender at key percentile markers for each of the knowledge *of* and *about science* scales is available in the initial OECD reports on PISA 2006 (OECD, 2007b, 2007c).

There are other differences between the science assessment in 2006 and in earlier assessments that need to be borne in mind when considering any comparison of performance. PISA 2006 incorporates a clearer distinction between *knowledge about* and *knowledge of science* than previous assessments, and includes an additional component on the relationship between science and technology. Further, science items used in 2006 needed, on average, less reading than the science items used in earlier assessments. Thus, a simple comparison of 2006 science scores with science scores from earlier cycles is confounded by changes in the nature of the assessment as well as changes in test design. These caveats aside, it is possible to conduct some analyses of trends on the subset of science items that were administered in each of the three PISA cycles.

Of the 103 science items used in PISA 2006, 22 were used in PISA 2003 and 14 in PISA 2000. Comparing performance on these items only, performance of Irish students has not changed significantly since 2000. Only in three OECD countries was any significant change evident. Between 2003 and 2006, mean scores on the comparable subset of items rose by over 20 points in Greece and Mexico, while in France, the mean decreased by 16 points (OECD, 2007b, Table A7.2).

It is also possible to compare the Irish science means with the OECD average in each of the three PISA cycles since 2000. In PISA 2000, Ireland's mean score for science was 513.4, compared to 505.4 in 2003 and 508.3 in 2006 (Table 3.17). In all three years, the mean science score for students in Ireland was significantly above the OECD average – albeit only just so in 2003 and 2006.

Finally, Ireland's rank in a 'league table' of countries can be examined. However, this type of analysis should be treated with considerable caution. The number of countries participating in each cycle is different, and ranking can mean that what are negligible differences in country scores are sometimes taken as substantive differences. For example, countries with mean scores within a few points of each other should not normally be considered substantively different, as it is conceivable that the relative positions could be swapped if the test were re-administered. To avoid suggesting significant differences where none exists, 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 PISA 2006, Ireland's is ranked 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 over time in Ireland's science ranking.

Table 3.17: A comparison of Irish and OECD mean scores on scientific literacy, 2000-2006

	Ireland		OECD		Diff IRL – OECD	Range of rank
	Mean	SE	Mean	SE		
2000	513.4	3.2	500.0	0.7	**+13.4**	9th – 12th of 27
2003	505.4	2.7	499.6	0.6	**+5.8**	9th – 16th of 29
2006	508.3	3.2	500.0	0.5	**+8.3**	10th – 16th of 30

Significant differences are in bold in the Diff column.

Summary

This chapter described the science achievement outcomes of students in PISA 2006, with a particular focus on Irish students. Ireland's mean score of 508 for overall scientific literacy is significantly higher than the OECD average, and places it between 10th and 16th of OECD countries. Twelve countries (including Finland and Canada) have significantly higher mean scores than Ireland, while nine (including the UK) do not differ significantly from Ireland. Ireland's mean is significantly above the OECD average on two of the three scientific competencies (*identifying scientific issues* and *using scientific evidence*) but not significantly different from the OECD average on *explaining phenomena scientifically*.

The spread of achievement in Ireland (exemplified by the gap between students at the 5th and 95th percentiles) was similar to the OECD average on the overall scale and on *identifying scientific issues* and *explaining phenomena scientifically*. On *using scientific evidence*, the gap between these key markers was smaller in Ireland (335) than the OECD average (352). For overall scientific literacy and for the science competencies, the percentages of Irish students performing at proficiency levels 5 and 6 (the highest levels) were similar to the OECD averages. However, the percentages of Irish students classified as below the baseline proficiency level of 2 were lower than the equivalent OECD country average percentages.

The means obtained by Irish students are significantly above the OECD average on *knowledge about science* and on *knowledge of Earth and space systems* but do not differ from the OECD average on *knowledge of living systems* or *physical systems.* The mean scores obtained by Irish students on the three *knowledge of science* domains are quite similar. This can be contrasted with the performance of students in countries such as Korea (ranked third of OECD countries on *Earth and space systems* but 20th on *knowledge of living systems*).

While, in Ireland, there are no significant gender difference in performance on overall scientific literacy, females significantly outperformed males on *identifying scientific issues* and on *knowledge about science* while males significantly outperformed females on *explaining phenomena scientifically*, *knowledge of physical systems* and *Earth and space systems*. Similar gender differences are found in OECD average scores. On overall scientific literacy, there were slightly more males than females at the highest and lowest proficiency levels, and marginally more females in the middle proficiency levels.

As 2006 was the first time that science was a major PISA domain, comprehensive trend data are unavailable for science performance. However, an examination of Ireland's relative position in country rankings for science over time suggests reasonable stability, with an overall performance comfortably above the OECD average in 2000, and just above it in 2003 and 2006.

Chapter 4
Reading and Mathematics Achievement

In this chapter, we look at performance on the PISA domains of reading and mathematics. There are three sections for each domain – a review of performance in PISA 2006, an analysis of gender differences in PISA 2006, and a consideration of trends in achievement over time. Readers are referred to explanatory notes in Chapter 3 that deal with comparing mean achievement scores (Inset 3.1 on page 29) and interpreting proficiency levels (Inset 3.2 on page 39).

Performance on Reading Literacy

As noted in Chapter 1, PISA assessed reading literacy as a major assessment domain in 2000, and as a minor assessment domain in 2003 and in 2006. The PISA 2006 reading test consisted of 28 items, with 25% of items designed to assess ability to retrieve information, 50% interpreting texts, and 25% reflecting on and evaluating the form and content of texts. The items were based on continuous texts (64%) and non-continuous texts (36%). Reading items (in one or two 30-minute blocks) appeared in 6 of the 13 test booklets[1]. For students who took one of the remaining 7 booklets, reading literacy scores were imputed, using variables such as school size and socioeconomic status. As in 2003, reading performance in 2006 was reported with respect to an overall reading scale only. One OECD country, the United States, is missing from tables describing PISA 2006 reading literacy. This is because there was a page-ordering error in one of the test booklets given to US students, which was deemed to result in biased scores.

Students in Ireland achieved a mean score of 517.3 on the PISA reading literacy scale. This is significantly higher than the OECD country average of 491.8[2] (as indicated by a ▲ symbol in the OECD Diff column in Table 4.1). Ireland ranked 5th among OECD countries (range of possible ranks: 4th to 6th), and 6th among all participating countries (range: 5th to 8th). Only four countries, including Finland and Canada, have significantly higher mean scores than Ireland. Three countries, including Australia and New Zealand, have mean scores that are not significantly different from Ireland. All other countries have significantly lower mean scores.

Spread of Achievement in Reading Literacy

Table 4.2 shows mean scores, and scores at key benchmarks (percentiles) on the reading literacy scale for the five highest scoring countries, for Ireland, and for selected comparison countries, including Germany, Northern Ireland and Denmark. The gap of 303 points between Irish students at the 5th (low-achieving students) and 95th (high-achieving students) percentiles is smaller than the corresponding OECD average of 324 points, indicating a relatively narrow range of reading achievement in Ireland, through Korea (289), Finland (265) and Denmark (293) had smaller gaps. The spread in

---

[1] This is equivalent to 60 minutes of testing time out of a total of 390 minutes in PISA 2006. Mathematics was allocated 120 minutes, and science 210 minutes.

[2] This relates to the OECD average of 500, which was established when reading literacy was a major assessment domain in PISA 2000.

Northern Ireland was 348 points, reflecting a poorer performance by students scoring at the 5th percentile.

The difference of 2 score points between students scoring at the 95th percentile in Northern Ireland and in Republic of Ireland is not statistically significant, but the score of Irish students at this key marker is almost 20 points higher than the OECD average. The relatively strong performance of higher-achieving students in Republic of Ireland on reading literacy can be contrasted with their performance in science, where they did less well than students in Northern Ireland, as well as several other countries.

Table 4.1: Mean achievement scores, standard errors and standard deviations on the reading literacy scale

	Mean	SE	SD	OECD Diff		Mean	SE	SD	OECD Diff
Korea	556.0	3.8	88	▲	Portugal	472.3	3.6	99	▼
Finland	546.9	2.1	81	▲	*Lithuania*	470.1	3.0	96	▼
Hong Kong-China	536.1	2.4	82	▲	Italy	468.5	2.4	109	▼
Canada	527.0	2.4	96	▲	Slovak Rep.	466.3	3.1	105	▼
New Zealand	521.0	3.0	105	▲	Spain	460.8	2.2	89	▼
Ireland	517.3	3.5	92	▲	Greece	459.7	4.0	103	▼
Australia	512.9	2.1	94	▲	Turkey	447.1	4.2	93	▼
Liechtenstein	510.4	3.9	95	▲	*Chile*	442.1	5.0	103	▼
Poland	507.6	2.8	100	▲	*Russian Fed.*	439.9	4.3	93	▼
Sweden	507.3	3.4	98	▲	*Israel*	438.7	4.6	119	▼
Netherlands	506.7	2.9	97	▲	*Thailand*	416.8	2.6	82	▼
Belgium	500.9	3.0	110	▲	*Uruguay*	412.5	3.4	121	▼
Estonia	500.7	2.9	85	▲	Mexico	410.5	3.1	96	▼
Switzerland	499.3	3.1	94	▲	*Bulgaria*	401.9	6.9	118	▼
Japan	498.0	3.6	102	o	*Serbia*	401.0	3.5	92	▼
Chinese Taipei	496.2	3.4	84	o	*Jordan*	400.6	3.3	94	▼
United Kingdom	495.1	2.3	102	o	*Romania*	395.9	4.7	92	▼
Germany	494.9	4.4	112	o	*Indonesia*	392.9	5.9	75	▼
Denmark	494.5	3.2	89	o	*Brazil*	392.9	3.7	102	▼
Slovenia	494.4	1.0	88	▲	*Montenegro*	392.0	1.2	90	▼
Macao-China	492.3	1.1	77	o	*Colombia*	385.3	5.1	108	▼
Austria	490.2	4.1	108	o	*Tunisia*	380.3	4.0	97	▼
France	487.7	4.1	104	o	*Argentina*	373.7	7.2	124	▼
Iceland	484.4	1.9	97	▼	*Azerbaijan*	352.9	3.1	70	▼
Norway	484.3	3.2	105	▼	*Qatar*	312.2	1.2	109	▼
Czech Republic	482.7	4.2	111	▼	*Kyrgyzstan*	284.7	3.5	102	▼
Hungary	482.4	3.3	94	▼	United States	m	m	m	
Latvia	479.5	3.7	91	▼	OECD average	491.8	0.6	99	
Luxembourg	479.4	1.3	100	▼	OECD total	483.8	1.0	107	
Croatia	477.4	2.8	89	▼					

(black)	Mean significantly higher than Ireland	▲	Above OECD average
(white)	Mean not significantly different from Ireland	o	At OECD average
(grey)	Mean significantly lower than Ireland	▼	Below OECD average

OECD countries are in regular font; partner countries are in italics.

Data not available for the US. Removed by the OECD for technical reasons.

Table 4.2: Percentage of students at key percentile markers on the reading literacy scale in Ireland, the five highest performing countries, and selected comparison countries

	Mean	5th		10th		25th		75th		90th		95th	
		Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Korea	556.0	399	9.7	440	7.9	503	4.8	617	3.4	663	4.3	688	5.0
Finland	546.9	410	4.8	441	3.8	494	2.9	603	2.2	649	2.5	675	2.8
Hong Kong-China	536.1	390	6.2	426	5.8	484	3.7	594	2.4	636	2.9	660	2.7
Canada	527.0	357	4.8	402	3.9	468	3.0	593	2.6	644	2.7	674	3.9
New Zealand	521.0	339	5.8	381	4.6	453	4.5	595	2.9	651	2.8	683	4.5
Ireland	517.3	358	6.3	395	5.5	457	4.7	582	3.9	633	3.5	661	4.3
Poland	507.6	335	4.8	374	4.6	441	3.5	579	3.2	633	3.4	663	4.0
Scotland	498.8	334	7.8	371	6.2	439	4.3	564	4.1	617	4.7	650	7.3
England	495.6	317	6.5	358	4.8	431	3.3	567	3.0	622	3.6	654	4.0
N. Ireland	495.3	311	8.3	352	8.7	424	5.5	572	3.2	627	4.8	659	6.0
Germany	494.9	299	9.7	350	8.0	429	5.9	573	3.4	625	3.7	657	3.7
Denmark	494.5	339	6.4	378	5.0	437	3.9	557	2.9	604	3.7	633	5.1
OECD	491.8	317	1.4	360	1.1	429	0.8	562	0.6	613	0.7	642	0.8
Wales	480.8	312	8.1	352	7.7	417	4.7	550	3.7	603	5.2	635	6.4

Performance on the Reading Proficiency Levels

Performance in reading literacy in 2006 was also reported with reference to reading proficiency levels. These were the same levels that were used in 2000 and 2003 (i.e., the cut-points in Table 4.3 were used in earlier PISA studies). As in the other PISA domains, the proficiency levels in reading represent descriptions of the types of tasks that students at varying levels of reading achievement are expected to perform successfully. There are five proficiency levels in reading (one fewer than in science and mathematics).

Level 5, the highest reading proficiency level, represents the most difficult reading tasks that students encounter in PISA. Students scoring at this level would be expected to successfully combine multiple pieces of deeply embedded information, infer which information in a text is relevant to the task, and analyse texts for which a discourse structure is not obvious or clearly marked (see Table 4.3 for a more complete description of each level). These descriptors are based on PISA reading literacy test items that the highest-achieving students in PISA were likely to answer correctly. In Ireland, almost 12% of students achieved at Level 5, compared with an OECD average of almost 9%. However, among the highest-scoring countries, Korea (22%), Finland (17%), Canada (15%) and New Zealand (16%) had higher percentages of students than Ireland scoring at Level 5 (Table 4.4). Level 5 is unbounded at the upper level. This means that some students achieving at this level may have higher-level reading skills that are not assessed by PISA.

Students scoring at Level 4 are likely to succeed on such tasks as sequencing multiple pieces of embedded information in a text with familiar content or form, inferring which information in a text is relevant, constructing the meaning of a section of text by taking the whole text into account, and following linguistic or thematic links over several paragraphs, often in the absence of clear discourse markers, to locate, interpret or evaluate embedded information. In Ireland, 37% of students achieved Level 4 or higher. While this compares favourably with the corresponding OECD average of

29%, it is lower than the five highest-scoring countries where between 40% (New Zealand) and 55% (Korea) of students scored at Level 4.

Table 4.3: Proficiency levels on the PISA 2006 reading literacy scale, and percentages of students achieving each level (Ireland and OECD average)

Level & score range	What students can typically do	IRL		OECD	
		%	SE	%	SE
5 625.6	Locate and possibly sequence or combine multiple pieces of deeply embedded information, some of which is outside the main body of the text. Infer which information in the text is relevant to the task at hand. Deal with highly plausible and/or extensive competing information. Critically evaluate or hypothesise, drawing on specialist knowledge. Deal with concepts that are contrary to expectation and draw on a deep understanding of long or complex texts. In continuous texts, can analyse texts whose discourse structure is not obvious or clearly marked, to discern relationships of specific parts of the text to its implicit theme or intention. In non-continuous texts, can identify patterns among many pieces	11.7	0.80	8.6	0.12
625.6 4 552.9	Locate and possibly sequence multiple pieces of embedded information, each of which may need to meet multiple criteria, in a text with familiar content or form. Infer which in formation in the text is relevant to the task. Use a high level of text-based inference to understand and apply categories in an unfamiliar context, and to construe the meaning of a section of text by taking into account the text as a whole. Deal with ambiguities, ideas that are contrary to expectation and ideas that are negatively worded. Use formal or public knowledge to hypothesise about or critically evaluate a text. Show accurate understanding of long or complex texts. Follow linguistic or thematic links over several paragraphs, in order to locate embedded information or to infer psychological or metaphysical meaning.	25.1	1.04	20.7	0.17
552.9 3 480.2	Locate, and in some cases, recognize, the relationship between pieces of information, each of which may need to meet multiple criteria. Deal with prominent competing information. Integrate several parts of a text in order to identify the main idea, understand a relationship, or construe the meaning of a word or phrase. Compare, contrast or categorise taking many criteria into account. Deal with competing information. Make connections or comparisons, give explanations or evaluate a feature of text. Demonstrate a detailed understanding of the text in relation to familiar everyday knowledge, or draw on less common knowledge. Use conventions of text organisation, where present, and follow implicit or explicit logical links such as cause and effect relationships across sentences or paragraphs in order to locate, interpret or evaluate information.	30.2	0.80	27.8	0.17
480.2 2 407.5	Locate one or more pieces of information, each of which may be required to meet multiple criteria. Deal with competing information. Identify the main idea in a text. Understand relationships, form or apply simple categories, or construe meaning within a limited part of the text when the information is not prominent and low level inferences are required. Make a comparison or connections between the text and outside knowledge, or explain a feature of the text by drawing on personal experience and attitudes. Follow logical and linguistic connections within a paragraph in order to locate or interpret information; or synthesise information across texts or parts of a text to infer the author's purpose.	20.9	0.93	22.7	0.17
407.5 1 334.8	Locate one or more pieces of explicitly stated information, typically meeting a single criterion, with little or no competing information in the text. Recognise the main theme or author's purpose in a text about a familiar topic, when required information in the text is prominent. Make a simple connection between information in the text and common, everyday knowledge. Can use redundancy, paragraph headings, or common print conventions to form an impression of the main idea of the text, or to locate information stated explicitly within a short section of text.	9.0	0.84	12.7	0.15
334.8 < 1	Students below Level 1 have a less than 50% chance of correctly answering Level 1 questions. Their reading literacy skills are not assessed by PISA.	3.2	0.55	7.4	0.14

Adapted from OECD (2007b) Figure 6.7, p.292-293

Students achieving Level 3 on the reading proficiency scale are likely to succeed on moderately difficult tasks, such as integrating several parts of a text to identify a main idea or evaluating a feature of a text. In Ireland, 67% of students achieved Level 3 or higher (Table 4.3). Although higher than the OECD average, this was lower than in all four countries with a significantly higher mean score than Ireland – Korea (82%), Finland (80%), Hong Kong-China (76%) and Canada (71%). In Northern Ireland, 57% of students achieved Level 3 or higher.

Students scoring at Level 2 in reading can understand relationships, form or apply simple categories, or construe meaning within a limited part of the text when the information is not prominent and low-level inferences are required. The OECD has cited this level as a minimum 'baseline' level if students are to meet their future challenges as citizens and as life-long learners. In Ireland, only 12% of students failed to achieve Level 2. This compares favourably with the OECD average of 20%, and the percentages in Poland (16%), Denmark (16%), and Northern Ireland (21%). However, proportionally more students in Ireland failed to reach the baseline reading proficiency level than in Korea (6%), Finland (5%), or Hong Kong-China (7%). Canada, a country with a mean reading literacy score that is also significantly higher than that of Ireland, had about the same percentage (11%) failing to reach Level 2.

Students scoring at Level 1 can only succeed on the most basic reading tasks in PISA, such as locating one or more pieces of explicitly stated information, and recognising the main theme or author's purpose in a text about a familiar topic, when required information in the text is prominent.

In Ireland, 3% of students scored below Level 1, compared to an OECD average of 7%. While less than 1% of students fell into this category in Finland, 8% of students in Wales, Northern Ireland, and Germany were below Level 1.

Table 4.4: Percentage of students at each overall reading proficiency level in Ireland, the five highest performing countries, and selected comparison countries

	Below Level 1		Level 1		Level 2		Level 3		Level 4		Level 5	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Korea	1.4	0.35	4.3	0.66	12.5	0.77	27.2	1.06	32.7	1.30	21.7	1.36
Finland	0.8	0.17	4.0	0.43	15.5	0.76	31.2	0.85	31.8	0.92	16.7	0.84
Hong Kong-China	1.3	0.28	5.9	0.64	16.5	0.84	31.5	1.12	32.0	0.93	12.8	0.81
Canada	3.4	0.36	7.6	0.41	18.0	0.80	29.4	1.03	27.2	0.84	14.5	0.71
New Zealand	4.7	0.47	9.9	0.68	18.7	0.81	26.4	0.83	24.5	0.83	15.9	0.79
Ireland	3.2	0.55	9.0	0.84	20.9	0.93	30.2	0.80	25.1	1.04	11.7	0.80
Poland	5.0	0.46	11.2	0.73	21.5	0.90	27.5	0.86	23.1	0.81	11.6	0.77
Scotland	5.2	0.73	11.5	0.99	23.5	1.05	30.9	1.27	20.6	1.14	8.5	0.87
England	6.8	0.61	12.1	0.67	22.5	0.78	28.7	0.78	20.6	0.88	9.2	0.69
N. Ireland	7.7	1.01	13.2	1.00	21.8	1.32	25.5	1.09	21.4	1.16	10.4	0.95
Germany	8.3	0.94	11.8	0.85	20.3	0.97	27.3	0.90	22.5	1.14	9.9	0.71
Denmark	4.5	0.59	11.5	0.75	25.7	0.92	31.8	0.98	20.7	0.91	5.9	0.61
OECD avg.	7.4	0.14	12.7	0.15	22.7	0.17	27.8	0.17	20.7	0.17	8.6	0.12
Wales	7.6	0.92	14.4	0.82	26.5	1.14	27.7	1.13	17.4	1.18	6.4	0.88

Gender Differences on Reading Literacy

This section compares the performance of male and female students on reading literacy in PISA 2006. The mean score of female students in Ireland (534.0) is significantly higher than that of males (500.2). The difference, 34 points, is just over one-third of an international standard deviation. A similar pattern can be observed in other comparison countries in Table 4.5, where differences, which are all statistically significant and in favour of females, range from 26 points in Scotland to 52 in Finland.

Table 4.5: Mean scores of male and female students and mean score differences on PISA reading literacy (Ireland and OECD average)

	Males		Females		Males - Females		Difference favouring …
	Mean	SE	Mean	SE	Diff	SED	
Korea	538.8	4.6	573.8	4.5	**−35.0**	5.91	Females
Finland	521.4	2.7	572.0	2.3	**−50.6**	2.84	Females
Hong Kong-China	520.3	3.5	551.4	3.0	**−31.2**	4.51	Females
Canada	511.1	2.8	543.0	2.5	**−31.9**	2.29	Females
New Zealand	501.7	3.6	539.1	3.6	**−37.4**	4.59	Females
Ireland	500.2	4.5	534.0	3.8	**−33.8**	4.90	Females
Poland	487.4	3.4	527.6	2.8	**−40.1**	2.93	Females
Scotland	485.4	5.0	512.1	4.1	**−26.4**	4.42	Females
England	480.8	3.6	510.0	3.1	**−29.2**	4.14	Females
N. Ireland	479.3	5.5	512.2	5.1	**−32.9**	8.03	Females
Germany	474.6	5.3	516.6	4.4	**−42.0**	3.86	Females
Denmark	479.5	3.6	509.3	3.5	**−29.8**	3.16	Females
OECD avg.	473.0	0.7	511.2	0.7	**−38.2**	0.79	Females
Wales	465.5	4.2	496.1	4.2	**−30.6**	3.99	Females

Significant differences shown in bold.

Gender differences in reading literacy can also be described in terms of reading proficiency levels. In Ireland, over twice as many male students (17%) as females (8%) scored at or below Level 1 (Table 4.6). The corresponding OECD average figures were 26% for males and 14% for females. More Irish female (15%) than male students (9%) achieved at the highest proficiency level (Level 5). This pattern was also observed at OECD level, where 11% of females and just 6% of males achieved the highest proficiency level.

Table 4.6: Percentages of males and females achieving each proficiency level on the reading scale (Ireland and OECD average)

	Ireland				OECD			
	Male		Female		Male		Female	
	%	SE	%	SE	%	SE	%	SE
Level 5	8.7	0.96	14.6	1.10	6.2	0.13	11.0	0.18
Level 4	21.4	1.17	28.6	1.59	17.4	0.21	24.2	0.23
Level 3	30.1	1.37	30.3	1.12	26.3	0.24	29.5	0.24
Level 2	23.1	1.43	18.7	1.29	24.3	0.23	21.2	0.23
Level 1	11.9	1.31	6.1	0.72	15.5	0.20	9.9	0.18
< Level 1	4.7	0.93	1.6	0.47	10.4	0.21	4.3	0.13

Trends in Reading Literacy (2000-2006)

This section considers differences in PISA reading literacy scores among comparison countries between 2000 (when reading literacy was a major assessment domain), and 2003 and 2006, when it was a minor domain. Three sets of comparisons are considered: 2000 with 2006, 2000 with 2003, and 2003 with 2006.

Readers should exercise caution in interpreting differences in trend scores over time. Issues that may affect the interpretation of differences include the different mix of items when reading moves from a major to a minor domain (i.e., significantly fewer reading items, and more in mathematics and science), removal of some items in the units used in 2003 (and 2006) compared with 2000, and reconfiguration of items used in 2000 into new clusters for 2003 and 2006, to provide adequate framework coverage. Any or all of these could have had an effect on item parameter estimation, and hence on equating results over two test administrations (OECD, 2007a).

Table 4.7 summarises trends in reading literacy in the highest-performing countries in 2006, in Ireland and in selected comparison countries, with respect to mean scores, and scores at the 5th and 95th percentile ranks. Significant differences are denoted by bold difference scores. Although Ireland's mean score dropped by just over 9 points between 2000 and 2006, the difference is not significant, nor are smaller drops at the 5th and 95th percentiles. There is a significant drop in achievement (22 points) at the 95th percentile in 2003 relative to 2000, but some of the shortfall was made up in 2006.

Table 4.7: Trends in reading achievement (mean and at the 5th and 95th percentiles) for Ireland, the five highest performing countries in 2006, and selected comparison countries

	Changes: 2006-2000			Changes: 2003-2000			Changes: 2006-2003		
	5th	Mean	95th	5th	Mean	95th	5th	Mean	95th
Korea	−2.9	**31.3**	**58.6**	−8.8	9.3	**30.3**	5.9	**21.9**	**28.3**
Finland	**19.3**	0.4	−6.3	9.3	−3.0	**−15.3**	10.1	3.4	9.1
Hong Kong-China	20.7	10.6	**13.6**	−14.5	**−15.9**	**−16.6**	**35.2**	**27.5**	**30.2**
Canada	−13.4	−7.3	−7.5	1.7	−6.4	**−18.1**	**−15.1**	−0.9	10.6
New Zealand	1.5	−7.8	−10.1	0.9	−7.2	−10.9	0.9	−0.5	0.8
Ireland	−2.5	−9.4	−8.2	3.1	−11.2	**−21.8**	−5.6	1.8	13.5
Poland	**30.7**	**28.5**	**32.4**	**26.3**	**17.5**	14.6	4.5	11.0	**17.8**
Scotland	m	**−26.8**	m	m	−10.0	m	m	**−16.8**	m
England	m	m	m	m	m	m	m	m	m
Northern Ireland	m	m	m	m	m	m	m	m	m
Germany	14.7	11.0	7.4	10.6	7.4	2.1	4.1	3.6	5.4
Denmark	13.5	−0.6	−12.3	12.1	−4.5	**−18.2**	1.4	2.2	5.9
OECD	**−13.5**	−6.2	−1.6	−7.0	−4.2	−3.6	−8.3	−6.2	1.4
Wales	m	m	m	m	m	m	m	m	m
US	m	m	m	m	−9.2	m	m	m	m

Source: OECD (2007c), Tables 6.3a, SG6
m: Data not available for comparison purposes
Significant differences shown in bold

Two of the countries in Table 4.7 show considerable progress between 2000 and 2006. Korea's mean score increased by 31 points (with most of the improvement coming between 2003 and 2006), while Poland's score increased by 29 points. Finland, the highest-scoring country in reading literacy in PISA 2000 and PISA 2003, had small mean score differences in all comparisons, but performance at the 95th percentile dropped significantly in 2003 from 2000, and performance at the 5th percentile improved significantly between 2000 and 2006. On average across OECD countries for which trend data were available, mean performance dropped by 6 points between 2000 and 2006. However, this increase is not statistically significant.

The OECD does not compare performance in Northern Ireland, England or Wales over time. This may be because, unlike Scotland, they are 'non-adjudicated' PISA regions, meaning that the OECD does not adjudicate the sample quality. Thus, as the UK as a whole was not included in the PISA 2003 dataset, trend data were provided only for Scotland. Data for Northern Ireland, available from other sources, show a mean score on reading literacy of 517 in both 2000 and 2003 (Gill, Dunn & Goddard, 2002; OECD, 2004b). Hence, the 2006 score of 495 (reported in OECD, 2007c) suggests a significant drop since 2000 and 2003.

Performance on Mathematical Literacy

As noted in Chapter 1, PISA assessed mathematics as a minor assessment domain in 2000 and as a major assessment domain in 2003. Mathematics reverted to minor domain status in 2006, using a subset of 48 items that had been administered in 2003. This section reviews performance in mathematics in 2006.

Ireland's mean score was 501.5, which is not significantly different from the OECD country average of 497.7 (Table 4.8). Ireland ranked 16th highest among OECD countries (range of ranks: 12th to 17th), and 22nd among 57 participating countries (range: 17th to 23rd).

Fifteen countries had mean scores that are significantly higher than Ireland's, including Chinese Taipei, Finland, Hong Kong-China and Korea. Countries with mean scores not significantly different from Ireland include the Czech Republic, Germany, Sweden, the UK, and Poland. Countries with mean scores that are significantly lower than Ireland's include Hungary, Norway and Italy.

Spread of Achievement in Mathematical Literacy

Table 4.9 shows the mean scores and scores at key percentile indicators on the mathematics scale for the five highest-scoring countries, for Ireland, and for the same set of comparison countries used in Chapter 3 and earlier in this chapter.

The difference in Ireland between the 5th and 95th percentiles is 268 points, which is lower than the corresponding OECD average of 299 points. Among the countries in Table 4.9, only Finland (267) and Wales (270) have differences close to Ireland's. Although overall performance in Ireland is not significantly different from the OECD average, the spread in achievement is relatively small, which can be interpreted as an indicator of equitable learning outcomes. Countries with large spreads in achievement include Chinese Taipei (334), Germany (325), and Northern Ireland (306). Although both the Republic of Ireland and Northern Ireland have mean scores that are close to the OECD country average, they have different patterns of achievement. The score of students at the 95th percentile (647) in Northern Ireland is greater than in the Republic of Ireland (634). Conversely, students at the 5th percentile in Northern Ireland (341) do less well than their counterparts in the Republic of Ireland (366).

Table 4.8: Mean achievement scores, standard errors and standard deviations on the mathematics scale

	Mean	SE	SD	OECD Diff		Mean	SE	SD	OECD Diff
Chinese Taipei	549.4	4.1	103	▲	*Latvia*	486.2	3.0	83	▼
Finland	548.4	2.3	81	▲	Spain	480.0	2.3	89	▼
Hong Kong-China	547.5	2.7	93	▲	*Azerbaijan*	476.0	2.3	48	▼
Korea	547.5	3.8	93	▲	*Russian Fed.*	475.7	3.9	90	▼
Netherlands	530.7	2.6	89	▲	United States	474.4	4.0	90	▼
Switzerland	529.7	3.2	97	▲	*Croatia*	467.2	2.4	83	▼
Canada	527.0	2.0	86	▲	Portugal	466.2	3.1	91	▼
Macao-China	525.0	1.3	84	▲	Italy	461.7	2.3	96	▼
Liechtenstein	525.0	4.2	93	▲	Greece	459.2	3.0	92	▼
Japan	523.1	3.3	91	▲	*Israel*	441.9	4.3	107	▼
New Zealand	522.0	2.4	93	▲	*Serbia*	435.4	3.5	92	▼
Belgium	520.3	3.0	106	▲	*Uruguay*	426.8	2.6	99	▼
Australia	519.9	2.2	88	▲	Turkey	423.9	4.9	93	▼
Estonia	514.6	2.7	80	▲	*Thailand*	417.1	2.3	81	▼
Denmark	513.0	2.6	85	▲	*Romania*	414.8	4.2	84	▼
Czech Rep.	509.9	3.6	103	▲	*Bulgaria*	413.4	6.1	101	▼
Iceland	505.5	1.8	88	▲	*Chile*	411.4	4.6	87	▼
Austria	505.5	3.7	98	▲	Mexico	405.7	2.9	85	▼
Slovenia	504.5	1.0	89	▲	*Montenegro*	399.3	1.4	85	▼
Germany	503.8	3.9	99	o	*Indonesia*	391.0	5.6	80	▼
Sweden	502.4	2.4	90	o	*Jordan*	384.0	3.3	84	▼
Ireland	501.5	2.8	82	o	*Argentina*	381.3	6.2	101	▼
France	495.5	3.2	96	o	*Colombia*	370.0	3.8	88	▼
United Kingdom	495.4	2.1	89	o	*Brazil*	369.5	2.9	92	▼
Poland	495.4	2.4	87	o	*Tunisia*	365.5	4.0	92	▼
Slovak Republic	492.1	2.8	95	▼	*Qatar*	318.0	1.0	91	▼
Hungary	490.9	2.9	91	▼	*Kyrgyzstan*	310.6	3.4	87	▼
Luxembourg	490.0	1.1	93	▼	OECD average	497.7	0.5	92	
Norway	489.8	2.6	92	▼	OECD total	483.7	1.2	98	
Lithuania	486.4	2.9	90	▼					

(black)	Mean significantly higher than Ireland	▲	Above OECD average
(white)	Mean not significantly different from Ireland	o	At OECD average
(grey)	Mean significantly lower than Ireland	▼	Below OECD average

OECD countries are in regular font; partner countries are in italics.

Table 4.9: Percentage of students at key percentile markers on the mathematics scale in Ireland, the five highest performing countries, and selected comparison countries

	Mean	5th		10th		25th		75th		90th		95th	
		Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Ch.Taipei	549.4	373	7.2	409	6.2	477	6.1	625	3.3	677	3.4	707	3.9
Finland	548.4	411	5.0	444	3.4	494	2.6	605	2.6	652	2.8	678	3.0
Hong Kong-Ch	547.5	386	6.1	423	6.4	486	4.5	614	3.1	665	3.5	692	4.8
Korea	547.5	392	7.1	426	6.1	485	4.3	612	4.4	664	6.9	694	8.2
Netherlands	530.7	382	6.0	412	5.0	467	4.6	596	2.7	645	3.3	672	4.3
N. Zealand	522.0	368	3.6	401	4.1	458	3.2	587	3.0	643	4.0	674	3.6
Denmark	513.0	371	5.0	404	4.3	456	3.4	572	2.8	621	3.4	649	4.3
Germany	503.8	339	8.5	375	6.8	437	4.9	574	3.9	632	3.8	664	4.6
Ireland	501.5	366	4.6	396	4.4	445	4.1	559	3.1	608	3.2	634	2.9
OECD avg.	497.7	346	1.1	379	0.9	436	0.7	561	0.6	615	0.8	645	0.9
Poland	495.4	353	3.3	384	3.4	435	2.8	557	3.3	610	3.7	638	3.5
US	474.4	328	7.6	358	5.8	411	4.8	537	5.0	593	4.8	625	4.8
Scotland	505.7	367	6.2	398	4.6	447	4.2	564	4.7	616	5.1	647	6.5
England	495.2	350	6.1	380	3.7	434	3.1	557	3.0	613	3.6	643	4.3
N. Ireland	493.9	341	6.8	373	4.9	427	4.3	561	3.5	616	3.4	647	4.8
Wales	484.4	351	4.0	378	3.7	428	3.0	541	3.4	592	4.4	621	4.9

Performance on the Mathematics Proficiency Levels

As in science and reading literacy, performance in mathematics can also be described in terms of proficiency levels. There are six proficiency levels in mathematics (Table 4.10), ranging from complex (Level 6) to easy (Level 1). As in the other assessment domains, the descriptors of achievement at each proficiency level are based on items that students at that level are likely to be successful on. Readers are referred to reports on PISA 2003 mathematics (e.g., Shiel, Perkins, Close & Oldham, 2007) for examples of, and commentary on, specific mathematics items at each level of proficiency.

Students achieving at Level 6 in mathematics are capable of engaging in advanced mathematical thinking and reasoning. They can conceptualise, generalise and utilise information based on investigations and modelling of complex problem situations. They can also demonstrate a mastery of symbolic and formal mathematical operations and relationships to develop new approaches and strategies for attacking novel situations. In Ireland, just 2% of students achieved at this level, compared to an OECD average of 3%, 5% in The Netherlands and between 9% and 12% in Korea, Hong Kong-China, Finland and Chinese Taipei. In the case of countries with mean scores not significantly different from Ireland's, 5% of students in Germany and 3% in Northern Ireland achieved at Level 6. Level 6 is unbounded at the upper end, meaning that some students may have higher levels of mathematics achievement than are assessed by PISA.

Table 4.10: Proficiency levels on the PISA 2006 mathematics scale, and percentages of students achieving each level (Ireland and OECD average)

Level & score range	What students can typically do	IRL		OECD	
		%	SE	%	SE
6 (669.3 and above)	Students can conceptualise, generalise, and utilise information based on their investigations and modelling of complex problem situations. They can link different information sources and representations and flexibly translate among them. Students at this level are capable of advanced mathematical thinking and reasoning. These students can apply this insight and understandings along with a mastery of symbolic and formal mathematical operations and relationships to develop new approaches and strategies for attacking novel situations. Students at this level can formulate and precisely communicate their actions and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situations.	1.6	0.25	3.3	0.09
5 (669.3 – 607.0)	Students can develop and work with models for complex situations, identifying constraints and specifying assumptions. They can select, compare, and evaluate appropriate problem solving strategies for dealing with complex problems related to these models. Students at this level can work strategically using broad, well-developed thinking and reasoning skills, appropriate linked representations, symbolic and formal characterisations, and insight pertaining to these situations. They can reflect on their actions and formulate and communicate their interpretations and reasoning.	8.6	0.67	10.0	0.12
4 (607.0 – 544.7)	Students can work effectively with explicit models for complex concrete situations that may involve constraints or call for making assumptions. They can select and integrate different representations, including symbolic ones, linking them directly to aspects of real-world situations. Students at this level can utilise well-developed skills and reason flexibly, with some insight, in these contexts. They can construct and communicate explanations and arguments based on their interpretations, arguments, and actions.	20.6	0.94	19.1	0.16
3 (544.7 – 482.4)	Students can execute clearly described procedures, including those that require sequential decisions. They can select and apply simple problem solving strategies. Students at this level can interpret and use representations based on different information sources and reason directly from them. They can develop short communications reporting their interpretations, results and reasoning.	28.6	0.90	24.3	0.16
2 (482.4 – 420.1)	Students can interpret and recognise situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures, or conventions. They are capable of direct reasoning and making literal interpretations of the results.	24.1	1.00	21.9	0.17
1 (420.1 – 357.8)	Students can answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. They are able to identify information and to carry out routine procedures according to direct instructions in explicit situations. They can perform actions that are obvious and follow immediately from the given stimuli.	12.3	0.93	13.6	0.15
< 1 (357.8 and below)	Students below Level 1 have a less than 50% chance of correctly answering Level 1 questions. Their mathematical literacy skills are not assessed by PISA.	4.1	0.50	7.7	0.14

Adapted from OECD (2007b) Figure 6.18, p.312

Students at Level 5 can select, compare and evaluate appropriate problem-solving strategies for dealing with complex problems, work strategically using broad, well-developed thinking and reasoning skills, and reflect on their actions and formulate and communicate their interpretations and reasoning. In Ireland, 10% of students achieved at Level 5 or higher, compared with an OECD average of 13%, and between 21% and 32% in the five highest-scoring countries. Countries with lower percentages of students at Level 5 or higher than Ireland included Wales (7%) and the United States (8%), while the percentage in Northern Ireland (12%) was about the same.

Table 4.11: Percentage of students at each mathematics proficiency level in Ireland, the five highest performing countries, and selected comparison countries

	Below Level 1		Level 1		Level 2		Level 3		Level 4		Level 5		Level 6	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Chinese Taipei	3.6	0.58	8.3	0.73	14.3	0.86	19.4	0.70	22.4	0.84	20.1	0.89	11.8	0.83
Finland	1.1	0.21	4.8	0.53	14.4	0.70	27.2	0.73	28.1	0.83	18.1	0.76	6.3	0.50
Hong Kong-China	2.9	0.45	6.6	0.63	14.4	0.84	22.7	1.07	25.6	0.90	18.7	0.78	9.0	0.82
Korea	2.3	0.52	6.5	0.71	15.2	0.69	23.5	1.07	25.5	0.99	18.0	0.78	9.1	1.29
Netherlands	2.4	0.61	9.1	0.82	18.9	0.94	24.3	0.88	24.1	1.06	15.8	0.76	5.4	0.64
New Zealand	4.0	0.32	10.0	0.79	19.5	0.99	25.5	1.13	22.1	1.02	13.2	0.75	5.7	0.50
Denmark	3.6	0.54	10.0	0.67	21.4	0.78	28.8	0.88	22.5	0.85	10.9	0.58	2.8	0.39
Scotland	3.8	0.67	11.7	0.91	24.1	1.11	28.2	1.21	20.0	1.19	9.4	0.93	2.7	0.54
Germany	7.3	1.01	12.5	0.80	21.2	1.13	24.0	1.07	19.4	0.90	11.0	0.78	4.5	0.50
Ireland	4.1	0.50	12.3	0.93	24.1	1.00	28.6	0.90	20.6	0.94	8.6	0.67	1.6	0.25
OECD	7.7	0.14	13.6	0.15	21.9	0.17	24.3	0.16	19.1	0.16	10.0	0.12	3.3	0.09
Poland	5.7	0.42	14.2	0.70	24.7	0.80	26.2	0.69	18.6	0.78	8.6	0.67	2.0	0.29
England	6.0	0.69	13.9	0.80	24.7	0.95	26.2	0.84	18.0	0.72	8.7	0.56	2.5	0.30
N. Ireland	7.3	0.85	15.3	0.96	23.2	1.12	23.3	1.29	18.8	0.98	9.6	0.77	2.6	0.34
Wales	6.0	0.54	16.1	0.90	27.0	1.09	27.5	1.09	16.1	1.06	6.0	0.63	1.2	0.26
US	9.9	1.15	18.2	0.91	26.1	1.21	23.1	1.09	15.1	0.99	6.4	0.66	1.3	0.24

Students at Level 4 can work effectively with explicit models for complex situations that may involve constraints or calls for assumptions, and select and integrate different representations, including symbolic ones. They can also construct and communicate explanations based on their own interpretations and arguments. In Ireland, 31% of students achieved Level 4 or higher, compared to an OECD average of 32%, and between 45% and 54% in the five highest-scoring countries.

Students at Level 3 can execute clearly described procedures, including those that require sequential decisions, select and apply simple problem-solving strategies, and interpret and use representations based on different information sources. In Ireland, 59% of students achieved at this or a higher level, compared with an OECD average of 57%. The highest scoring countries had between 70% and 74% of students at or above Level 3. Countries with proportionally fewer students than Ireland at or above Level 3 included Poland (55%) and Northern Ireland (54%).

Students at Level 2 can interpret and recognise situations in contexts that require no more than a direct inference, extract relevant information from a single source, and make use of a single representational mode. According to the OECD (2004b), Level 2 is a basic minimum level of mathematics required to succeed in adult life and in future education. Students at Level 1 can complete tasks involving familiar contexts where all the relevant information is provided and questions are clearly defined. They can identify and carry out routine procedures. Students below Level 1 are unable to complete successfully the most basic PISA mathematics tasks. In Ireland, 16% of students do not achieve Level 2, indicating, according to the OECD, a lack of adequate mathematical literacy skills. While this compares favourably with the corresponding OECD country average of 21%, it is well below Finland (6%), Korea (9%) and Hong Kong-China (10%). Interestingly, Chinese Taipei, the highest-scoring country in mathematics, has 17% of students at or below Level 1 – almost the same percentage as Ireland. Countries in the comparison group with more students at or below Level 1 than Ireland include Poland (20%), England (20%) and Northern Ireland (23%).

Gender Differences on Mathematics

This section compares the performance of male and female students on mathematics in PISA 2006. Male students in Ireland achieved a mean score of 507.3, while females achieved a mean of 495.8. The difference, 11.5 points, or about one-eighth of an international standard deviation, is statistically significant. The OECD average difference, 11.2 points, also favours males, and is statistically significant. Twenty-two of 30 OECD countries had a gender difference in favour of males. The largest difference was in Austria (22.6 points). Qatar was the only participating country in which females did better.

Among countries in Table 4.12, the largest gender difference (19.5 points) is in Germany (where males did better). Korea and Northern Ireland had small differences in favour of males (9.3 and 6.5 points respectively), and neither is statistically significant.

Table 4.12: Mean scores of male and female students and mean score differences on PISA mathematics (Ireland and OECD average)

	Males		Females		Males - Females		Difference favouring …
	Mean	SE	Mean	SE	Diff	SED	
Chinese Taipei	555.6	4.7	542.5	5.9	**13.1**	6.65	Males
Finland	554.3	2.7	542.5	2.6	**11.7**	2.61	Males
Hong Kong-China	555.4	3.9	539.8	3.7	**15.6**	5.48	Males
Korea	552.0	5.3	542.8	4.5	9.3	6.33	None
Netherlands	536.9	3.1	524.1	2.8	**12.8**	2.80	Males
New Zealand	527.5	3.1	516.8	3.6	**10.6**	4.71	Males
Denmark	518.2	2.9	507.9	3.0	**10.3**	2.77	Males
Scotland	513.5	4.2	497.7	4.0	**15.8**	3.97	Males
Germany	513.2	4.6	493.7	3.9	**19.5**	3.72	Males
Ireland	507.3	3.7	495.8	3.2	**11.5**	4.09	Males
OECD	503.2	0.7	492.0	0.6	**11.2**	0.71	Males
Poland	500.0	2.8	490.9	2.7	**9.1**	2.57	Males
England	503.9	3.0	486.7	3.1	**17.2**	3.46	Males
Northern Ireland	497.1	5.3	490.6	4.4	6.5	8.06	None
Wales	492.5	3.1	476.3	3.5	**16.1**	3.33	Males
US	478.6	4.6	470.1	3.9	**8.5**	2.89	Males

Significant differences shown in bold in the Diff column.

Performance by gender can also be examined with reference to proficiency levels. Table 4.13 gives the percentages of males and females at each proficiency level in Ireland and on average across OECD countries. In Ireland, marginally more females (17%) than males (16%) scored at or below Level 1, while significantly more males (12%) than females (8%) achieved above Level 5. On average across OECD countries, a slightly smaller percentage of males (20%) than females (22%) scored at or below Level 1, while a higher percentage of males (16%) than females (11%) scored above Level 5.

Table 4.13: Percentages of males and females achieving each proficiency level on the mathematics scale (Ireland and OECD average)

	Ireland				OECD			
	Male		Female		Male		Female	
	%	SE	%	SE	%	SE	%	SE
Level 6	2.4	0.41	0.9	0.25	4.2	0.12	2.5	0.09
Level 5	9.9	0.90	7.4	0.90	11.3	0.17	8.7	0.16
Level 4	21.9	1.12	19.4	1.35	19.5	0.21	18.6	0.22
Level 3	27.3	1.25	29.7	1.36	23.6	0.22	25.0	0.23
Level 2	23.1	1.48	25.2	1.09	20.9	0.22	22.9	0.23
Level 1	11.4	1.29	13.2	1.07	12.9	0.19	14.3	0.20
< Level 1	4.1	0.70	4.1	0.62	7.5	0.17	8.0	0.17

Trends in Mathematics (2003-2006)

As mathematics was a major assessment domain in 2003 and a minor domain in 2006, it was possible to monitor trends between the two years in detail. All 48 mathematics items administered in 2006 had been administered in 2003. Although more items were assessed in mathematics than in reading in 2006, the OECD (2007a) nevertheless urge caution in interpreting the significance of score differences since items were regrouped in clusters in 2006, and presented in a different context (most students were asked to complete relatively large proportions of science items in 2006, but not in 2003).

Table 4.14 summarises score differences in the five highest-performing countries in mathematics, in Ireland and in key comparison countries, between 2003 and 2006. A significant mean score difference was observed in just one country, Scotland, between the two years, with a drop of 18 points.[3] There were significant declines at the 95th percentile in two countries – The Netherlands and Denmark. Ireland's mean score dropped by just 1 point, well within the margins of error on the test.

The OECD did not report differences in mathematics in Northern Ireland or in other non-adjudicated countries between the two years. Again, data for Northern Ireland show mean scores of 515 in 2003 (OECD, 2004b) and, as indicated in Table 4.9, 494 in 2006. Hence, it would seem that performance declined in Northern Ireland between 2003 and 2006.

Differences in mathematics performance between 2000 and 2003 were reported by the OECD (2004b) for subsets of items that were administered in both years – those dealing with Space & Shape and Change & Relationships. Neither mean performance, nor performance at key benchmarks (5th, 10th, 25th, 75th or 90th percentiles) changed

[3] Significant difference in mean scores were also observed in a small number of countries not in Table 4.12, including Greece (+14 points), Mexico (+20) and France (–15).

in Ireland between the two years. The OECD average mean score, and scores at five of the six percentile ranks, increased on Change & Relationships; there were no differences on Space & Shape.

Table 4.14: Trends in mathematics achievement (mean and at the 5th and 95th percentiles) for Ireland, the five highest performing countries and selected comparison countries in 2006 and 2003

	Changes: 2006-2003		
	5th	Mean	95th
Chinese Taipei	m	m	m
Finland	5.0	4.1	−2.3
Hong Kong-China	11.8	−2.9	−7.6
Korea	4.6	5.2	4.1
Netherlands	−3.2	−7.2	**−11.6**
New Zealand	9.0	−1.5	−8.8
Denmark	10.5	−1.3	**−13.1**
Scotland	m	**−18.1**	m
Germany	15.0	0.8	2.2
Ireland	5.5	−1.4	−6.8
OECD avg.	2.0	−2.0	**−5.5**
Poland	9.4	5.2	−1.7
England	m	m	m
N. Ireland	m	m	m
Wales	m	m	m
US	5.4	−8.5	−13.1

Source: OECD (2007c), Tables 6.3b, 6.3d, S6h

Summary

Reading and mathematics were assessed as minor domains in PISA 2006. Hence, less detail is available on performance in these domains than in the major domain of science.

The mean score in reading literacy of students in Ireland was significantly higher than the OECD average, and merited a ranking of 5th (95% Confidence Interval: 4th to 6th) among OECD countries, and 6th (5th to 8th) among all participating countries. The scores of students in Ireland at the 5th and 95th percentiles were well above the corresponding OECD average scores, though students in a number of countries, including Korea, Finland, Canada and New Zealand, had scores that were significantly higher than Ireland at the 95th percentile. On the reading proficiency scales, 12% of students in Ireland achieved at the highest level (Level 5), compared with 22% in Korea and 17% in Finland. Just 12% of students in Ireland achieved at the lowest proficiency levels (Level 1 or below) – a figure that was markedly better than the corresponding OECD average (20%).

In Ireland, and across all participating countries for which data on reading literacy were available in PISA 2006, female students achieved a mean score that was significantly higher than males, while females were more strongly represented at the highest level on the reading proficiency scale, and less well represented at and below the lowest level. The mean score difference in Ireland, one-third of an international standard deviation, is marginally smaller than the OECD average country difference.

In 2006, students in Ireland achieved a mean score that was 2 score points higher than in 2003, and 9 points lower than in 2000. Neither difference is statistically significant. Indeed, among comparisons made to date involving Ireland, only one difference reached statistical significance: students in Ireland at the 95th percentile in 2003 achieved a score that was significantly lower than that of students scoring at the same benchmark in 2000.

In mathematics in PISA 2006, students in Ireland achieved a mean score that is not significantly different from the OECD average. Ireland ranked 16th highest among OECD countries (95% Confidence Interval: 12th to 17th), and 22nd among 57 participating countries (17th to 23rd). Ireland did less well in mathematics than a number of countries with lower mean scores in reading literacy, including The Netherlands, Estonia, Switzerland and Denmark.

Students in Ireland scoring at the 5th percentile in mathematics achieved a score that was well above the corresponding OECD country average. At the 95th percentile, students in Ireland achieved a score that was significantly below the OECD country average for the same benchmark. This indicates a relatively poor performance among higher-achieving students in Ireland. The differences in scores between students in Ireland scoring at the 5th and 95th percentiles is among the lowest for countries participating in PISA 2006 mathematics. On the mathematics proficiency scale, just 1.6% of students in Ireland achieved the highest proficiency level (Level 6) compared with an OECD average of 3.3%. Sixteen percent of students in Ireland achieved at or below the lowest proficiency level (Level 1).

Male students in Ireland had a significantly higher mean score than females – a pattern found in 21 other OECD countries. Further, the size of the difference in Ireland (and in other countries) was considerably smaller than in reading literacy. On the mathematics proficiency scale, slightly more females than males in Ireland scored at or below Level 1, while more males than females scored at or above Level 5. Similar patterns were observed in OECD average percentages.

Since mathematics was a major assessment domain in PISA 2003, performance in PISA 2006 is compared with PISA 2003 but not with PISA 2000. The mean score of students in Ireland dropped by just 1 point between 2003 and 2006 – a difference that is not statistically significant. Performance in Ireland at the 5th percentile improved by 6 scale points, while performance at the 95th percentile declined by 7 points. Neither difference is statistically significant.

Chapter 5
PISA and the Junior Certificate Examination

This chapter relates Irish student performance on PISA 2006 and performance on the 2006 Junior Certificate Examination. Attention is focused on science, English, and mathematics performance, as these are most closely related to the PISA literacy domains of science, reading, and mathematics. Science was the major domain in PISA 2006, the year in which the first cohort of students was examined on the revised Junior Certificate science syllabus (rJCSS)[1]. Consequently, much of this chapter focuses on student performance on science.

The chapter is divided into five main sections. First, some background is provided on national performance on the Junior Certificate Examination in 2006. Second, performance on the examination by the PISA 2006 cohort is described. Third, performance on PISA and on the Junior Certificate Examination is related, with particular attention to performance on science. Fourth, the PISA science framework and test items are examined from the vantage point of the rJCSS, including ratings of the familiarity of PISA science items to rJCSS students. In the final section, the rJCSS is examined in terms of the PISA science framework, including the relative emphasis accorded to elements of the PISA framework.

The Junior Certificate Examination, 2006

In 2006, just under 58,000 students – almost evenly divided between females and males – sat the Junior Certificate Examination (Table 5.1). The percentage of candidates who sat a science examination (86%) is almost identical to that found in previous PISA cycles, with a larger percentage of females (17%) than males (10%) not taking science.

Table 5.1: Number of Junior Certificate candidates and numbers and percentages taking science, by gender and overall

	N		% of total candidates	
	JC candidates	Science candidates	Taking science	Not taking science
Female	28547	23571	82.6	17.4
Male	29397	26357	89.7	10.3
Total	57944	49928	86.2	13.8

Most science students (90.3%) sat an examination relating to the rJCSS, while only 19 students were examined on the Science (Local Studies) syllabus. Thus, 9.6% of students were not examined on the revised syllabus. For most of the remainder of this

[1] Readers requiring more information on the revised syllabus and how it differs from its predecessor are directed to NCCA (2006) or Eivers et al. (2006).

chapter, where Junior Certificate Examination science results are described, they refer to the combined results of those examined on any of these science syllabi. Of those taking science, approximately two-thirds took the subject at Higher Level, with proportionally more females (72%) than males (63%) taking it at Higher Level (Table 5.2). Overall, females tended to achieve slightly higher grades than males. For example, 38% of males, compared to almost 45% of females, achieved an A or a B grade at Higher Level[2]. At Ordinary Level, 29% of females and 26% of males were awarded A or B grades.

Table 5.2: Percentage of Junior Certificate science candidates taking Higher or Ordinary Level papers, overall and by gender

	N	% taking Higher	% taking Ordinary
Female	23571	72.4	27.6
Male	26357	62.7	37.3
Total	49928	67.3	32.7

Table 5.3 shows similar data for Junior Certificate Examination English and mathematics uptake in 2006. The first point to note is that students taking these subjects have the option of one of three levels – Higher, Ordinary or Foundation – whereas science can be taken only at Higher or Ordinary Level. As with science, close to two-thirds of students took English at Higher Level, with a larger proportion of female than male candidates choosing the Higher Level option. In contrast, less than half of students chose to take mathematics at Higher Level, and gender differences in the percentages taking Higher Level were smaller than for science or English.

Table 5.3: Junior Certificate 2006 English and mathematics candidates, split by level taken and gender

		N	% taking Higher	% taking Ordinary	% taking Foundation
English	Female	28188	71.7	25.2	3.1
	Male	28937	58.5	36.7	4.8
	Total	57125	65.0	31.0	4.0
Maths	Female	28076	44.3	46.5	9.2
	Male	28889	40.7	47.6	11.7
	Total	56965	42.5	47.1	10.4

Females were more likely than male students to be awarded A or B grades in English, at each of the three levels. As a corollary, at least twice as many males as females obtained an E grade or lower at each of the three levels. In mathematics, at each level, at least half of those who sat the mathematics examination received an A or a B grade – much higher than for English or science. While females tended to outperform males in science and English, the picture was less clear in mathematics. For example, the percentages of males and females obtaining A or B grades were very similar at Higher Level. At Ordinary Level, females were more likely to obtain an A or a B, while at Foundation level, males were more likely to obtain these grades.

[2] Full details of all Junior Certificate 2006 outcomes, including grade allocation by gender for each subject level, are available from *www.examinations.ie*.

Junior Certificate Examination Performance Scales

It is difficult to compare student overall performance on examinations since students typically take different subjects at different levels. For this reason, a 12-point scale which allows comparison of student grades on a particular subject across three examination levels (Higher, Ordinary and Foundation) has been developed and used in a number of Irish studies (e.g., Cosgrove et al., 2005; Kellaghan & Dwan, 1995; Martin & Hickey, 1993). The relationship between the scale and student grades is shown in Table 5.4. Students' scores for a set of subjects can be summed to produce one overall performance score – often referred to as the OPS – for each student. For the present study, we have not created an *overall* score, but have examined student performance separately for science, English, and mathematics. Therefore, we refer to students' Junior Certificate Performance Score (JCPS) on a subject.

Table 5.4: Relationship between grade and level and JCPS score

Level	JCPS score											
	12	11	10	9	8	7	6	5	4	3	2	1
Higher	A	B	C	D	E	F						
Ordinary				A	B	C	D	E	F			
Foundation							A	B	C	D	E	F

Table 5.5 presents national data for Junior Certificate Examination 2006 candidates. As can be seen, the highest average JCPS (9.2) was for science, followed by English (9.1), with a considerably lower JCPS for mathematics (8.4). These averages, to some extent, reflect the relatively small proportion taking mathematics at Higher Level, and the lack of a Foundation level for science. In each of the three subject areas, females obtained a higher mean score than males. The gap was widest for English, where females obtained a mean JCPS of 9.5, compared to a score of 8.7 for males.

Table 5.5: Mean science, English and mathematics JCPS for 2006 Junior Certificate examination candidates, overall and by gender

	Science		English		Mathematics	
	N	Mean	N	Mean	N	Mean
Male	26316	9.0	28933	8.7	28866	8.2
Female	23553	9.4	28186	9.5	28061	8.6
All	49869	9.2	57119	9.1	56927	8.4

Data are unweighted as the table shows the population of Junior Certificate 2006 students

PISA Students and Junior Certificate Examination Performance

Table 5.6 shows JCPSs obtained by students who participated in PISA in 2006. As with the national data for the Junior Certificate Examination 2006, females outperformed males in each of the three subjects, with the difference most pronounced in English. The mean JCPS for science and English are quite similar, while the mean JCPS for mathematics is between 0.6 and 0.7 lower. However, average JCPSs among PISA participants are slightly higher than the equivalent national averages for Junior Certificate Examination 2006 students. A possible explanation is that while the students *selected* to participate in PISA were a representative national sample, weaker students were over-represented among those who *did not participate*. Readers should be aware that this does not mean that, as a consequence, PISA presents an overly positive picture of student performance in Ireland. PISA data are adjusted to take into account student (and school) non-participation with the intention of preventing inflated national estimates of performance.

Table 5.6: Mean JCPS for PISA 2006 participants, split by gender and overall

	Science			English			Mathematics		
	N	Mean	SE	N	Mean	SE	N	Mean	SE
Male	2060	9.2	0.07	2171	9.0	0.08	2170	8.6	0.09
Female	1981	9.5	0.07	2242	9.8	0.05	2243	8.8	0.08
All	4041	9.3	0.06	4413	9.4	0.05	4413	8.7	0.07

Figures shown are based on data from Junior Certificate 2005 and 2006.

Not all PISA participants sat the Junior Certificate Examination in 2006, and previous PISA national reports (e.g., Cosgrove et al., 2005) have sometimes found variation in average subject JCPS across years. Therefore, Table 5.7 was constructed to compare the mean JCPS for each subject, split by the year in which the Junior Certificate was examined. For each subject, the mean JCPS for PISA 2006 participants who took the Junior Certificate in 2005 is slightly higher than that obtained by the 2006 cohort. However, the difference is highly likely to be explained by the fact that 15-year-olds who differ in terms of the grade level in which they are enrolled also tend to differ academically. Typically, those in the more senior grade tend to be higher achieving students.

Table 5.7: JCPS scores for PISA 2006 participants, split by year in which Junior Certificate was completed

	Year sat Junior Cert	N	Mean	SE
Science	2005	1600	9.4	0.06
	2006	2441	9.3	0.06
English	2005	1742	9.5	0.06
	2006	2670	9.4	0.06
Mathematics	2005	1742	8.8	0.08
	2006	2671	8.6	0.08

Average grades on Junior Certificate subjects can vary from year to year, and the science curriculum on which most students were examined differed between 2005 and 2006. Therefore, it seems that PISA students who sat the Junior Certificate Examination in 2006 *only* are the most appropriate group with which to compare PISA and Junior Certificate Examination results. Such a comparison reveals that the differences between PISA and national JCPSs are slightly reduced, but that PISA students still tend to obtain slightly higher JCPSs than students nationally.

Comparing Performance on PISA and the Junior Certificate Examination

There is a strong relationship between performance on PISA domains and performance on the equivalent Junior Certificate Examination subjects (Table 5.8). Performance on the overall PISA science scale correlated .70 with Junior Certificate Examination science performance, with little difference by year in which the Junior Certificate Examination was taken. Performance on each of the three science competency scales is also highly correlated with Junior Certificate science (ranging from .68 for *using scientific evidence* to .69 for *explaining phenomena scientifically*). Correlations are also strong between Junior Certificate English and PISA reading (.64) and between Junior Certificate mathematics and PISA mathematics (.69).

Table 5.8: Correlations between performance on elements of PISA and Junior Certificate Science, English and mathematics performance

	r	SE
JC science + PISA overall science	**.702**	0.01
JC science + Explaining phenomena scientifically	**.688**	0.01
JC science + Identifying scientific issues	**.668**	0.01
JC science + Using scientific evidence	**.677**	0.01
JC English + PISA reading	**.636**	0.01
JC mathematics + PISA mathematics	**.687**	0.01

Significant correlations are shown in bold.

Performance on a particular PISA domain is reasonably closely related to performance on the equivalent Junior Certificate Examination subject. However, the PISA domains are themselves strongly intercorrelated (.88 for science and mathematics, .86 for science and reading, and .82 for reading and mathematics). Indeed, the correlations between PISA domains are stronger than the correlations with their equivalent Junior Certificate subject. Thus, consideration must be given to the idea that PISA is not only assessing domain-specific skills and knowledge, but also some underlying trait.

A Closer Look at Science

The previous section related performance on PISA to JCPS. Table 5.9 presents the mean PISA science scores of those who studied science at Ordinary or Higher Levels and those who did not study science at all for the Junior Certificate. While those who took Junior Certificate science at Ordinary Level obtained a mean score that is significantly lower than those who studied at Higher Level, their mean score does not differ significantly from that of those who did not study science for the Junior Certificate.

Very similar patterns of performance were found on the competency scales and on *knowledge of* and *about* science, meaning that Ordinary Level science students did not significantly outperform non-science students on any of the scientific competencies or knowledge areas assessed. Because science is the only PISA domain where it is relatively common for students not to take the equivalent Junior Certificate subject, it is not possible to perform similar analyses for the domains of reading and mathematics. However, the apparent lack of a science 'advantage' for Ordinary Level students was also reported in Cosgrove et al. (2005) and Shiel et al. (2001). While an intuitively simple explanation is that Ordinary Level science students are academically weaker than non-science students, comparisons of the mean scores for reading and mathematical literacy reveal no significant differences between the two groups. One possible explanation for the lack of difference between the science performance of the two groups is that non-science students have studied elements of PISA science in other subjects (such as home economics or geography).

Table 5.9: Mean PISA science scores, by uptake of Junior Certificate science

	Frequencies		Science	
	%Total	%Available	Mean	SE
Higher Level	61.5	63.9	**550.9**	2.5
Ordinary Level (Ref group)	26.6	27.6	441.1	3.4
Did not study science	8.1	8.4	444.0	6.9
Missing	3.7	0.0	426.2	12.6

Significant differences in bold.

As well as mean performance levels, we can examine proficiency levels. As shown in Table 5.10, students who took Junior Certificate science at Higher Level are clustered in the middle and top proficiency levels. Only 3% failed to reach Level 2 (the baseline proficiency level), compared to an OECD average of 19%.

Table 5.10: Percentage of students at science proficiency levels, by science course uptake

	OECD		Higher		Ordinary		Non-science	
	%	SE	%	SE	%	SE	%	SE
Level 6	1.3	0.04	1.8	0.29	0.0	0.05	-	-
Level 5	7.7	0.10	13.0	0.87	0.4	0.23	1.1	0.91
Level 4	20.3	0.16	31.1	1.10	4.3	0.72	8.8	1.71
Level 3	27.4	0.17	34.5	1.22	23.0	1.81	21.1	2.84
Level 2	24.0	0.17	16.5	1.01	38.9	1.89	34.0	4.02
Level 1	14.1	0.15	2.9	0.46	26.5	1.74	25.9	3.64
< Level 1	5.2	0.11	0.2	0.10	6.9	0.96	9.1	1.88

However, even among Higher Level students, the percentage attaining proficiency level 6 (1.8%) was not markedly higher than the OECD average of 1.3%. Among those who did not study science at Junior Certificate, no students reached Level 6, while only 1% reached Level 5. Among Ordinary Level science students, only one half of a percent reached proficiency levels 5 or 6. At the other extreme, one-third of Ordinary Level science students and 35% of non-science students failed to reach baseline proficiency in science.

PISA Items Through the Lens of the rJCSS

Unlike traditional curriculum-based assessments such as the Junior Certificate Examination in science, PISA attempts to assess 'real-life' scientific literacy. Nonetheless, there clearly is variation in the extent to which different science curricula prepare students for the PISA science assessment. For example, almost one-quarter of PISA items relate to *living systems*. Students studying only a physical sciences curriculum will be less familiar with some of the scientific information underpinning these items than students taking biology as a subject. Such differences in preparedness for PISA items can be found at the student level and at the national level. For example, the relative strength of French students on *using scientific evidence* has been attributed to a strong curriculum emphasis on scientific reasoning and on the analysis of data and experiments (OECD, 2007b).

In this section, PISA and Junior Certificate science are compared in terms of the type of content covered and competencies required. PISA items were rated for expected familiarity for an Irish student studying Junior Certificate science, and categorised by location on the rJCSS. The Junior Certificate Examination itself is also examined in terms of the PISA science framework. Similar comparisons were carried out in 2000 and 2003 for the major PISA domains.

Ratings were assigned by three subject experts who had extensive knowledge of the Junior Certificate science curriculum. Ratings were made independently, using a 3-point rating scale (described below). A meeting was held to discuss and agree ratings on those items on which there was a difference of more than one point between raters (e.g., 1, 1, 3). Ratings were collated, and each test booklet was assigned scale ratings, depending on the familiarity level of the mix of items included in the booklet. For example, the combination of science items in booklet X might mean that it was assigned a higher concept familiarity score for Irish students than the combination of items in booklet Y. In this way, it was possible not only to describe item familiarity for Irish students, but to examine the link between familiarity and student performance.

The Rating Scales

Each PISA science item was rated on two dimensions – concept and competency – using 3-point scales (1 = not familiar, 2 = somewhat familiar, 3 = very familiar). The concept scale was described to raters as a measure of student familiarity with, or knowledge of, a scientific principle in its abstract form. Raters were required to identify the concept(s) underlying the item and to rate its familiarity for Third year students (the typical grade for a 15-year-old). The competency scale, which required raters to identify the *type of scientific understanding* needed to answer the question, was developed in a different manner. The PISA framework identifies nine scientific competencies, grouped into three broad competency categories. The expert raters agreed a pre-defined familiarity rating for each of the nine competencies. For example, the competency of *recognising the key features of a scientific investigation* was assigned a rating of '3', meaning that Irish students were expected to be very familiar with it. When rating items on the competency scale, raters had to check an item's broad competency category, decide which of the three competencies contained therein best matched the item, and apply the pre-assigned competency rating to the item.

Raters had the option of specifying different concept and competency familiarity ratings for Ordinary and Higher Level students.

Familiarity With PISA Items' Concept and Competency

Almost half of all PISA science test items were rated as based on concepts that were very familiar to Irish students, while 47% were described as somewhat familiar (Table 5.11). Ratings did not differ by level (Ordinary or Higher). Only 4% of PISA items were perceived to be based on concepts unfamiliar to Irish students. In terms of competencies, 63% of items were described as based on competencies that were somewhat familiar to Irish students, while 37% were judged to be based on very familiar competencies.

Table 5.11: PISA science items rated on concept and competency familiarity

	N	Not familiar	Somewhat familiar	Very familiar
Concept	103	3.9	46.6	49.5
Competency	103	0.0	63.1	36.9

There was some variation in item concept familiarity, depending on how items were classified using the PISA science framework (Table 5.12). For example, none of the items relating to *Earth and space systems*, to *living systems*, or to *scientific enquiry* was rated as 'not familiar' to Irish students. Over 80% of items dealing with *physical systems* were rated as being based on very familiar concepts, as were 75% of *technology systems* items and 64% of *living systems* items. In contrast, only 19% of items dealing with *scientific explanations* and 27% of items dealing with *Earth and space systems* were believed to be based on concepts that were very familiar to Irish Third year science students.

Table 5.12: Percentage of items within each PISA knowledge of/about category, categorised by levels of concept familiarity to Third year students

	Knowledge about		Knowledge of			
	Scientific enquiry (N=24)	Scientific explanations (N=21)	Earth & space systems (N=11)	Living systems (N=22)	Physical systems (N=17)	Technology systems (N=8)
Not familiar	0.0	9.5	0.0	0.0	5.9	12.5
Somewhat familiar	58.3	71.4	72.7	36.4	11.8	12.5
Very familiar	41.7	19.0	27.3	63.6	82.4	75.0
Total %	100.0	100.0	100.0	100.0	100.0	100.0

All PISA science items that fell into the competency category of *explaining phenomena scientifically* were rated as being somewhat familiar to Irish Third year students in terms of the underlying competency. Thirty-five percent of items assessing the competency of *identifying scientific issues* were described as somewhat familiar, while the competency underlying 65% of such items was described as very familiar (Table 5.13). Finally, the specific competency underlying approximately three-quarters of items assessing the competency of *using scientific evidence* was described as very familiar to Third year students.

Table 5.13: Percentage of items within each PISA Competency category categorised by various levels of familiarity to Third year students

	Explaining phenomena scientifically (N=49)	Identifying scientific issues (N=23)	Using scientific evidence (N=31)
Not familiar	–	–	–
Somewhat familiar	100	34.8	25.8
Very familiar	0	65.2	74.2
Total	100.0	100.0	100.0

Effects of Familiarity on Test Performance

PISA 2006 used a 'rotated booklet design', involving 13 different test booklets. Test items were divided into 'blocks' of science, reading or mathematics items, with each block estimated to take approximately 30 minutes to complete. For example, the 108 science items were divided into seven blocks of items. Each booklet was composed of four blocks of items, and each contained at least two science blocks. The items encountered by students depended on the booklet they were assigned, and no student answered all 108 science items. Thus, based on the combination of science items in a particular booklet, different booklets could be assigned different overall concept and competency familiarity ratings. This enabled us to examine how the overall familiarity of the combination of items related to how students performed on the PISA test.

All familiarity ratings were made with reference to the content of the rJCSS. Consequently, Table 5.14 shows the correlations between rated familiarity and performance on PISA only for students who took the rJCSS. As can be seen, the correlations between the adjudged familiarity of the test items and actual performance range from weak to weak-to-moderate. The strongest correlation (.15) is between competency familiarity and performance amongst students who took the rJCSS at Higher Level, while the weakest correlation (non-significant) is between competency familiarity and performance for students who took the rJCSS at Ordinary Level.

Table 5.14: Correlations between concept and competency familiarity and performance on PISA science

		r	SE
Concept	Higher Level	**0.140**	0.03
	Ordinary Level	**0.115**	0.04
Competency	Higher Level	**0.149**	0.03
	Ordinary Level	0.087	0.04

Significant correlations are shown in bold. The t-value for the non-significant correlation is 1.97.

The relationship between science performance and test familiarity is considerably weaker than the relationships reported in previous Irish national reports for reading and mathematics (Cosgrove et al., 2005; Shiel et al., 2001). However, the Irish national report on PISA 2000 also examined the relationship between science test familiarity and achievement, and revealed similar results to those shown in Table 5.14. Thus, although the reasons are unclear, the relationship between test item familiarity and performance seems to be somewhat weaker for science than for reading or mathematics.

Locating PISA Items in the rJCSS

Raters were asked to locate PISA items within the rJCSS. As well as sections 1A – 3C (encompassing biology, chemistry and physics), raters could use an additional location of 'general'. This category was used when the item did not fall into any of the main sections of the syllabus, but covered general scientific skills cited in the syllabus introduction as skills that students were expected to acquire as part of their studies. For example, an item which required students to know some of the characteristics of a scientific test can be related back to page 4 of the syllabus (DES, 2003), where student understanding of the scientific method and the concept of a valid experiment is described as a syllabus objective.

Sixteen percent of PISA items were classified as not being covered in the rJCSS, while 18% were categorised as assessing general scientific skills (Table 5.15). A further 29% were classified as assessing topics or skills covered in biology, with 22% categorised as physics items, and only 15% as chemistry items. Although raters had the option to supply different locations, depending on syllabus level, all agreed locations were identical for Higher and Ordinary syllabi.

Of the 68 items which were assigned a specific location within the syllabus, 44.1% were located within the biology element of the syllabus. However, within biology, PISA items were not evenly distributed across the main three sections. For example, while 18 items fell under section 1C (animals, plants and micro-organisms), no items fell under 1B (human biology – the skeletal/muscular system, the senses and human reproduction). Of the 16 items described as not covered by the rJCSS, five related to the *knowledge of Earth and space systems* (and may have been covered in the Geography syllabus), three to *knowledge of technology systems*, two to *physical systems* and none to *living systems*. *Knowledge about scientific enquiry* and *scientific explanations* accounted for a further six of the items not on the syllabus.

Table 5.15: PISA science items categorised by location within the rJCSS

Location			N	%	Overall %
Not on rJCSS		–	16	15.5	15.5
Biology	**1A**	Human bio. – food, digestion, assoc. systems	12	11.7	
	1B	Human bio. – skeletal/muscular, senses, reprod.	0	0.0	
	1C	Animals, plants, micro-organisms	18	17.5	29.1
Chemistry	**2A**	Classification of substances	4	3.9	
	2B	Air, oxygen carbon dioxide & water	3	2.9	
	2C	Atomic structure, reactions & compounds	8	7.8	14.6
Physics	**3A**	Force & energy	14	13.6	
	3B	Heat, light & sound	5	4.9	
	3C	Magnetism, electricity & electronics	4	3.9	22.3
General		–	19	18.4	18.4
Total		–	103	100.0	100.0

Table 5.16 summarises the overall division of PISA science items by PISA framework classification and by location within the syllabus. While 23% of items relate to scientific enquiry, these are unevenly distributed by syllabus location. Over half of items assessing scientific enquiry (12% of all items) are located in the general

syllabus category, while only one item (1%) is located in a chemistry section. Items assessing scientific explanations are more evenly spread across the various syllabus areas, although, again, only one item (1%) is located in a chemistry section. Almost half of items relating to *knowledge of Earth and space systems* are described as not being on the syllabus, while almost all items relating to *living systems* fall in a biology section. Approximately two-thirds of *physical systems* items (11% of all items) were located in the chemistry section of the syllabus; items relating to *technology systems* tended to fall in a physics section.

Table 5.16: PISA science items, by rJCSS location and PISA classification

	N	% Sc. enquiry	% Sc. explanation	% Earth & space	% Living	% Physical	% Technology	% Row total
Not on	16	2.9	2.9	4.9	0.0	1.9	2.9	15.5
Biology	30	2.9	4.9	1.0	20.4	0.0	0.0	29.1
Chemistry	15	1.0	1.0	1.0	0.0	10.7	1.0	14.6
Physics	23	4.9	6.8	2.9	0.0	3.9	3.9	22.3
General	19	11.7	4.9	1.0	1.0	0.0	0.0	18.4
Total	103	23.3	20.4	10.7	21.4	16.5	7.8	100.0

The rJCSS Through a PISA Lens

As well as examining PISA test items from the point of view of the rJCSS, it is possible to examine the rJCSS from a PISA perspective. While examinations and marking schemes do not represent the totality of a syllabus, they can be taken as an indicator of the importance placed on elements of a syllabus. For this reason, we examined the rJCSS marking schemes (Higher and Ordinary Levels) to determine the proportion of marks allocated to various elements of the PISA framework for science.

The basic marking scheme for both levels is based on a maximum of 600 marks, with 390 (65%) allocated to the terminal written examination, 60 marks (10%) allocated to Coursework A, and 150 marks (25%) allocated to Coursework B. Within each of these broad subdivisions, specific marks are allocated to specific examination questions or Coursework titles. For example, each Coursework A title is allocated 2 marks. Each discrete question or title was classified using the PISA framework (e.g., Coursework A title 'Separate mixtures using a variety of techniques: filtration, evaporation, distillation and paper chromatography' was classified under the PISA *knowledge of* category of *physical systems* and under the competency of *explaining phenomena scientifically*).

The classifications assigned were then grouped at the subdivision level (Coursework A and B and written examination) and overall for both Higher and Ordinary Level. We have reported for each of the subdivisons, as well as providing an overall indication of the emphasis each element of the framework receives in the rJCSS. Readers should remember that the PISA framework was designed to guide the development of a written test of scientific literacy, and the interpretation of student performance on that test. It is a framework for dealing with what is on paper, and its suitability as a framework for actual, hands-on scientific experimentation and investigation is less clear. Therefore, caution should be used in interpreting some of the following tables.

The written Junior Certificate Examination papers at both Higher and Ordinary Level reveal a heavy emphasis on the PISA competency of *explaining phenomena scientifically*, particularly at Ordinary Level (Table 5.17). At Higher Level, 91% of the marks allocated related to the competency of *explaining phenomena scientifically*, rising to almost 98% for Ordinary Level. Seven percent of marks at Higher Level related to the competency of *using scientific evidence*, while the remaining 2% were allocated to the competency of *identifying scientific issues*. At Ordinary Level, 1.5% of marks were allocated to the competency of *using scientific evidence*, and almost 1% was allocated to *identifying scientific issues*.

Table 5.17: The percentage of marks for the 2006 rJCSS written examination papers relating to each of the PISA competency categories

	Explaining phenomena scientifically	Identifying scientific issues	Using scientific evidence
Higher	90.8	2.3	6.9
Ordinary	97.7	0.8	1.5

Looking at the written examination papers in terms of the PISA categories of *knowledge of* or *knowledge about* science, there was a clear focus on *physical systems* and *living systems*, with little or no emphasis placed on other categories (Table 5.18). While 64% of the marks for the Higher Level paper were allocated to *knowledge of physical systems*, and 31% to *living systems*, only 3% were allocated to *knowledge about scientific enquiry*, and less than 2% to *knowledge of technology systems*. No marks were allocated to *knowledge about scientific explanations* or *knowledge of Earth and space systems*. Similarly at Ordinary Level, 64% of marks were allocated to *knowledge of physical systems*, 31% to *knowledge of living systems*, while the remaining 5% were allocated to *knowledge about scientific enquiry*. No marks were allocated to *knowledge about scientific explanations*, *knowledge of Earth and space systems* or *technology systems*.

Table 5.18: PISA knowledge of/about science categories, and the percentage of marks for the 2006 rJCSS written examination papers allocated to each

	Knowledge about		Knowledge of			
	Scientific enquiry	Scientific explanations	Earth & space systems	Living systems	Physical systems	Technology systems
Higher	3.1	0.0	0.0	31.0	64.4	1.5
Ordinary	5.4	0.0	0.0	30.8	63.8	0.0

When Coursework marks were related to PISA competencies, there was much less of a focus on *explaining phenomena scientifically* than was found in the written papers. While 33% of Coursework A marks were allocated to *explaining phenomena scientifically*, 53% were allocated to *using scientific evidence* and 13% to *identifying scientific issues* (Table 5.19). For Coursework B, 40% of marks were allocated to *using scientific evidence* and 60% to *identifying scientific issues*, with no marks for *explaining phenomena scientifically*.

Table 5.19: PISA competencies, and the percentage of marks for the 2006 rJCSS Coursework (A and B) allocated to each

	Explaining phenomena scientifically	Identifying scientific issues	Using scientific evidence
A	33.33	13.33	53.33
B	0.0	60.0	40.0

Knowledge of and *about* classifications were also slightly more diverse for Coursework than for the written paper. While over half of Coursework A related to *knowledge of physical systems*, 27% related to *scientific enquiry* and 17% to *living systems* (Table 5.20). All of Coursework B was categorised under *knowledge about scientific enquiry*.

Table 5.20: PISA knowledge of/about science categories, and the percentage of marks for the 2006 rJCSS Coursework (A and B) allocated to each

	Knowledge about		Knowledge of			
	Scientific enquiry	Scientific explanations	Earth & space systems	Living systems	Physical systems	Technology systems
A	26.7	0.0	0.0	16.7	56.7	0.0
B	100.0	0.0	0.0	0.0	0.0	0.0

Overall, 62% of marks for Higher Level students were allocated to the PISA competency of *Explaining phenomena scientifically*, with only 18% allocated to *identifying scientific issues* (Table 5.21). Twenty percent of marks related to the PISA competency of *using scientific evidence*. At 67%, the percentage of marks allocated to *Explaining phenomena scientifically* at Ordinary Level was even higher, with only 17% allocated to *identifying scientific issues* and 16% to *using scientific evidence*.

Table 5.21: The percentage of total marks for the 2006 rJCSS relating to each of the PISA competency categories

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

Overall, at both Higher and Ordinary levels, almost half of total marks were allocated to *knowledge of physical systems*, 22% to *living systems*, and close to 30% were allocated to *knowledge about scientific enquiry* (Table 5.22). No Junior Certificate science marks were allocated to *scientific explanations* or to *knowledge of Earth and space systems*. While *knowledge of technology systems* accounted for 1% of total mark allocation at Higher Level, no marks were allocated to it at Ordinary Level.

Table 5.22: PISA knowledge of/about science categories, and the percentage of total marks for the 2006 rJCSS allocated to each

	Knowledge about		Knowledge of			
	Scientific enquiry	Scientific explanations	Earth & space systems	Living systems	Physical systems	Technology 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

Summary

The 86% of Junior Certificate 2006 students who sat a science examination is similar to the percentages reported in previous years. Females were less likely to take science than males, but tended to achieve higher grades. Approximately two-thirds of science and English students took their subject at Higher Level, compared to just under half of mathematics students. Amongst PISA students, as in the population nationally, females did slightly better than males on each of the three subjects, with the gender gap smallest for mathematics.

There was a significant positive relationship between performance on PISA domains and performance on the comparable Junior Certificate Examination subject. For example, students who obtained high scores on the PISA science scale tended to obtain a high JCPS for science. The correlation between performance on a PISA domain and the corresponding Junior Certificate subject was strongest (.70) for the overall PISA science scale and Junior Certificate science. However, the intercorrelations between PISA domains were stronger than the correlations between the domains and their equivalent Junior Certificate subjects.

A matching exercise was conducted between PISA items and the rJCSS. Seventeen percent of PISA items dealt with topics or skills perceived to be not covered in the syllabus. At 30%, biology was somewhat over-represented, while at 14%, chemistry was somewhat under-represented in the PISA item pool. In terms of the concepts underlying items and the competencies assessed, almost all PISA science items were rated as either somewhat or very familiar to Third year rJCSS students. Familiarity scores were assigned to test booklets, based on the ratings for the combination of items they contained. However, due to the largely familiar nature of most items, there was not a large spread of familiarity scores between booklets (i.e., all booklets scored highly on an index of familiarity). Only weak correlations were found between booklet familiarity and performance on aspects of PISA science.

The Junior Certificate science syllabus, as exemplified by the 2006 overall marking schemes for Higher and Ordinary Levels, was categorised using the PISA science framework. At both levels, almost half of marks were allocated to *knowledge of physical systems*, approximately 30% to *knowledge about scientific enquiry*, and 22% to *knowledge of living systems*. No marks were allocated to *knowledge about scientific explanations* or to *knowledge of Earth and space systems*, while few or no marks (depending on level) were allocated to *knowledge of technology systems*.

Chapter 6
Student Characteristics

In this chapter, relationships between selected student characteristics and achievement are described. Performances in the three PISA assessment domains are highly inter-correlated and typically have similar relationships with explanatory variables (an exception is gender, which was discussed in Chapters 3 and 4). Consequently, the analyses reported here will largely focus on associations with scientific literacy. Unless otherwise stated, readers can assume that relationships with reading and mathematical literacy are similar to those reported for science.

The chapter is divided into three main sections. The first describes students' background characteristics and the results of analyses of the relationship between achievement and parental occupation, parental education, family size, resources in the home, and students' engagement in paid and unpaid work. The second section focuses on the student in school, including the relationship between PISA science and grade level, syllabus, homework, experiences of being bullied, and absenteeism. The third section tracks changes in student characteristics in PISA studies over time.

Student Background Characteristics

Most students (94%) were categorised as 'native' Irish, meaning that they or at least one of their parents had been born in Ireland (Table 6.1). Although these students obtained a higher mean scientific literacy score than students categorised as either first or second generation Irish[1], the differences are not statistically significant. Analyses across all OECD countries fail to find a clear-cut relationship between performance in PISA and either immigrant status or the proportion of immigrant students in a country's population (OECD, 2007b). For example, in both Germany and Denmark, which have considerably larger immigrant populations than Ireland, 'native' students outperformed first and second generation students. However, in Australia, which has an even larger proportion of non-native students, no significant difference was found between the mean science scores of immigrant (first or second generation) and native Australian students (OECD, 2007c, Table 4.2c).

Table 6.1: Mean scores of Irish students on the science scale, by nationality

	Frequencies		Science	
	%Total	%Available	Mean	SE
Native (Reference category)	91.5	94.4	510.4	3.0
2nd Generation	1.0	1.1	498.0	14.9
1st Generation	4.4	4.5	500.4	14.6
Missing	3.1	0.0	**461.9**	10.3
All Available	96.9	100.0	509.8	3.1

Significant differences in bold.

[1] 'First generation' refers to students who, as well as both their parents, were born outside Ireland. Second generation' refers to Irish-born students whose parents were born in another country.

OECD analyses suggest that rather than simply examining immigrant/native status, other attributes (e.g., socioeconomic factors and language spoken at home) also need to be considered. In an Irish context, the percentage of students not classified as native (6%) is much larger than the 2% who spoke a language other than English or Irish at home. However, only those students who spoke 'an other' language manifest a significantly poorer mean science score than the main body of students (Table 6.2). Large mean differences favouring native speakers were also found for reading (49 points) and maths (57 points), but the difference (61 points) is statistically significant only for science.

Table 6.2: Mean science scores of Irish students, by language spoken at home

	Frequencies		Science	
	%Total	%Available	Mean	SE
Irish/English (Reference category)	95.7	98.0	510.8	3.1
Other language	2.0	2.0	**449.6**	22.1
Missing	2.4	0.0	**455.3**	12.0
All Available	97.6	100.0	509.6	3.2

Significant differences in bold.

Just 4% of students indicated that they were only children, while at the opposite end of the spectrum, 19% had four or more siblings (Table 6.3). As family size increases beyond one sibling, mean scores begin to decrease. The highest mean score in science (523) was obtained by students with one sibling. These students significantly outperformed students with three siblings (by 17 points) or with four or more siblings (by 39 points).

Table 6.3: Mean science scores of Irish students, by number of siblings

	Frequencies		Science	
	%Total	%Available	Mean	SE
None	4.0	4.1	519.9	7.4
One (Reference category)	24.1	24.6	522.5	3.8
Two	30.2	30.8	515.8	3.8
Three	21.5	21.9	**505.5**	4.3
Four or more	18.1	18.5	**483.8**	4.7
Missing	2.1	0.0	**454.1**	12.6
All Available	97.9	100.0	509.5	3.2

Significant differences in bold.

Parental Occupation and Education

Students were asked for information about their parents' occupations and the nature of the work they performed. The resultant data were coded using the International Socioeconomic Index (ISEI) (Ganzeboom, de Graaf, & Treiman, 1992). The ISEI scale ranges from 16 to 90, with higher scores reflecting higher socioeconomic status. Where information on two parents' occupations was available, the occupation with the highest ISEI score was used to provide the 'family' ISEI score. For analysis and reporting purposes, ISEI scores were split into thirds.

There was a clear relationship between ISEI and science performance (Table 6.4), with a difference of approximately 30 points between the mean scores of the low and medium ISEI categories, and the medium and high categories. For example, students in the high family ISEI category attained a mean science score of 542. This is well above the national Irish mean of 508 and significantly higher than the mean scores of students classified as low or medium on ISEI.

Table 6.4: Mean science scores of Irish students, by parental occupation

	Frequencies		Science	
	%Total	%Available	Mean	SE
Low	31.5	32.9	**480.7**	4.1
Medium	32.9	34.4	**512.8**	2.9
High (Reference category)	31.3	32.7	542.3	3.4
Missing	4.2	0.0	**428.7**	9.2
All Available	95.8	100.0	511.9	3.0

Significant differences in bold.

As with ISEI, information on parental education was combined (highest level taken) to produce a 'family' level index. The highest mean science score was obtained by the 25% of students with at least one parent who had completed a third-level degree, while the lowest mean score was obtained by the 3% whose parents had not progressed beyond primary school (Table 6.5). The 43% of students whose parents had completed Senior Cycle only are used as the reference group against which other groups of students are compared. As can be seen, this group obtained a significantly higher mean than students whose parents had completed only primary school or only Junior Cycle, and a significantly poorer mean than students whose parents had completed a third-level certificate, diploma or degree.

Table 6.5: Mean science scores of Irish students, by parental education

	Frequencies		Science	
	%Total	%Available	Mean	SE
None/primary	2.9	3.0	**440.2**	8.9
Junior cycle	8.1	8.3	**476.6**	5.8
Senior cycle (Ref category)	41.5	42.7	497.4	3.3
3rd level cert/diploma	20.9	21.4	**519.9**	4.0
3rd level degree/postgrad	23.9	24.5	**544.1**	4.3
Missing	2.7	0.0	**441.0**	11.6
All Available	97.3	100.0	510.2	3.2

Significant differences in bold.

Economic, Social and Cultural Status

PISA uses an index of socioeconomic status called ESCS (Economic, Social and Cultural Status) which combines information about parental education and occupation, and cultural and educational resources in the home. The scale is designed to have a mean of zero and a standard deviation of one, with higher scores reflecting higher SES and resources. In 2006, Ireland's mean ESCS score of −0.02 was slightly below the OECD mean. This is because Irish students' slightly above average score on parental education and occupation was counterbalanced by a below average score on cultural and educational resources in the home. When ESCS scores were split into thirds, students categorised as coming from high ESCS homes obtained a mean science score of 548, significantly outperforming students with low or medium ESCS scores (by 75 and 40 points, respectively) (Table 6.6).

Table 6.6: Mean science scores of Irish students, by economic, social and cultural status

	Frequencies		Science	
	%Total	%Available	Mean	SE
Low	32.9	33.5	**472.8**	4.4
Medium	32.6	33.2	**507.8**	3.0
High (Reference category)	32.6	33.3	548.1	3.4
Missing	1.9	0.0	**447.4**	13.8
All Available	98.1	100.0	509.5	3.2

Significant differences in bold.

While there is a strong link between ESCS and science achievement, the link is slightly weaker in Ireland than across the OECD as a whole. ESCS scores account for 12.7% of the variation in Irish science scores, compared to an OECD average of 14.4%. Contrasting examples are New Zealand and Germany, where ESCS explains 16% and 19% of the variance in test scores, respectively. This means that socioeconomic background is less predictive of student performance on PISA science in Ireland than (for example) in Germany.

Resources in the Home

In this section we relate achievement to aspects of the home environment, such as educational and cultural resources, affluence indicators, and books in the students' homes.

Educational and Cultural Resources in the Home

PISA uses an index of home educational resources, which is a composite of students' responses regarding the availability of certain resources in their home. Like ESCS, the index was constructed with an OECD mean of zero and a standard deviation of one, with higher scores indicating higher levels of resources. Ireland's mean of −0.11 indicates that Ireland ranked 21st of the 30 OECD countries in terms of availability of educational resources in the home. Availability of the more 'technological' resources – such as a computer, calculator, internet access, and educational software – matched or exceeded the OECD average. For example, roughly nine out of ten students in Ireland had access to a computer for schoolwork, which reflects the OECD average. However, the pattern for more traditional educational resources is somewhat different. In particular, the percentage of Irish students with access to a study desk at home (86%) was 7% below the OECD average.

For each education-related resource, possession is associated with significantly higher achievement. For example, Irish students with a study desk achieved a mean science score of 514.3, which is one-third of a standard deviation higher than the mean of students with no desk (482.3). In the case of computer access for school work, the corresponding gap in scientific literacy is greater than half a standard deviation (53 points).

PISA also uses an index of cultural possessions, based on the availability of classic literature, poetry books and works of art in the home. Ireland's mean of −0.19 was well below the OECD average of zero, giving it a rank of 26th of 30 OECD countries. Table 6.7 shows Irish student average scores by quartiles of the index. Students who were classified as having very high levels of cultural possessions averaged the highest mean science score (551), significantly outperforming students with very low, low or high scores on the index.

Table 6.7: Mean science scores of Irish students, by level of cultural possessions

	Frequencies		Science	
	%Total	%Available	Mean	SE
Very low	22.8	23.4	**481.5**	4.5
Low	27.6	28.3	**498.1**	3.3
High	22.4	22.9	**507.9**	3.9
Very high (Ref category)	24.7	25.3	551.1	3.8
Missing	2.5	0.0	**447.1**	11.1
All Available	97.5	100.0	509.9	3.2

Significant differences in bold.

Affluence Indicators

Unlike cultural possessions, Irish students were above the OECD average on almost all 'affluence indicators' (household possessions thought to indicate wealth), including mobile phones, cars and dishwashers. For example, over three-quarters of Irish students reported having three or more televisions in their home, compared to an OECD average of 52%, while over 80% of Irish students had a dishwasher at home, compared to an OECD average of 66%.

Most affluence indicators were positively associated with achievement. For example, the mean science score of 528.9 obtained by students with three or more computers in their home is significantly higher than the mean obtained by students with one computer (by 18 points) or no computer (by 73 points). In contrast, indicators related to television were negatively linked to achievement. Students living in a household with three or more televisions obtained a science mean score of 504 (Table 6.8). While this is very close to the Irish average, it is significantly lower than the mean score of students with one or two televisions in the home (by 31 and 23 points, respectively).

Table 6.8: Mean science scores of Irish students, by number of TVs in the home

	Frequencies		Science	
	%Total	%Available	Mean	SE
None	0.3	0.3	495.7	27.7
One	3.7	3.8	**535.8**	11.8
Two	17.2	17.6	**527.3**	4.8
Three plus (Ref category)	76.5	78.3	504.4	3.0
Missing	2.3	0.0	**452.6**	10.9
All Available	97.7	100.0	509.6	3.2

Significant differences in bold.

In a related vein, students with a premium cable TV package at home were significantly outperformed by students without such a package (498.9 versus 527.5, respectively). Combining information on both indicators reveals a difference of almost 64 points between the science mean of students with one TV and no premium cable package and the mean of students with premium cable and three or more TVs. It may be noted that less than 3% of Irish students fall into the former category.

Books in the Home

The distribution of books in Irish homes was very similar to the OECD average, with roughly one in ten students having between zero and ten books in their home, and, at the other extreme, almost 9% having more than 500 (Table 6.9). Irish students most commonly said that they had between 26 and 100 books, and such students averaged 503 on the science scale. There is a clear positive association between science achievement and the number of books in the home. Students with no more than ten books averaged 434 on the science scale, more than a full standard deviation below the mean of 551 obtained by students with more than 500 books.

Table 6.9: Mean science scores of Irish students, by number of books in the home

	Frequencies		Science	
	%Total	%Available	Mean	SE
0 to 10	10.0	10.3	**434.3**	5.7
11 to 25	15.4	15.8	**466.3**	4.4
26 to 100 (Ref category)	28.7	29.4	503.0	3.5
101 to 200	19.8	20.3	**535.2**	3.5
201 to 500	15.4	15.8	**558.3**	3.7
Over 500	8.3	8.5	**551.3**	6.1
Missing	2.4	0.0	**460.5**	11.3
All Available	97.6	100.0	509.5	3.2

Significant differences in bold.

Interaction with Parents

Although not included as part of the international PISA student questionnaire, Irish students answered five additional questions about how often they engaged in a range of activities with their parents. The frequency of student-parent interactions varied considerably depending on the specific activity (Table 6.10). For example, while one-third of students never or hardly ever discussed political or social issues with their parents, only 5% reported never or hardly ever discussing with their parents how they were getting on in school. The activities most frequently engaged in were eating with parents or just chatting (75% and 65%, respectively, did so several times a week).

Each of the activities listed showed a similar relationship with achievement. Broadly speaking, the more frequently students engaged in any of the activities, the higher their achievement scores tended to be, with the relationship most pronounced for discussing politics and social issues. For example, the mean science score of 484.3 obtained by students who never or hardly ever spoke to their parents about politics and social issues is 63 points lower than the mean of 547.2 obtained by students who did so several times a week.

Table 6.10: Frequency with which Irish students engaged in various activities with their parents

	N	Never or hardly ever	A few times a year	About once a month	Several times a month	Several times a week
Discuss political or social issues	4303	34.0	20.4	15.0	19.3	11.3
Discuss books, films or television programmes	4296	12.3	10.8	12.8	29.4	34.7
Discuss how well doing at school	4286	4.9	7.2	11.9	28.0	48.0
Eat dinner around the table	4293	6.1	4.2	3.4	11.9	74.5
Spend time just chatting	4297	5.8	4.3	5.7	19.6	64.7

The five variables were combined to form a parental interaction scale. Students who reported low levels of parental interaction obtained a mean of 491, over 40 points lower than the mean of 532 obtained by students with high levels of interaction (Table 6.11). The relationship between interaction and achievement was more pronounced for males than for females. Females with low levels of parental interaction averaged 33 points lower on the science scale than females with high levels of interaction; for males, the difference is 49 points.

Table 6.11: Mean science scores of Irish students, by level of parental interaction

	Frequencies		Science	
	%Total	%Available	Mean	SE
Low	30.6	33.2	**490.8**	4.1
Medium	30.6	33.2	**518.8**	3.2
High (Reference category)	31.0	33.6	531.6	3.5
Missing	7.7	0.0	**442.6**	8.5
All Available	92.3	100.0	513.8	3.0

Significant differences in bold.

Engagement in Paid and Unpaid Work

Students in Ireland answered extra items regarding their engagement in paid and unpaid work during term time. Unfortunately, as these are nationally added questions, we cannot gauge if the amount of hours worked by Irish students is unusual or relatively typical of 15-year-olds internationally. Almost two-thirds (63.4%) of Irish students engaged in some paid work during school term, while almost half (57.3%) engaged in unpaid work (such as work for the family business or minding siblings). Considering *only those* who engaged in some form of work, students spent 6 hours 24 minutes per week engaged in paid work, 3 hours 56 minutes in unpaid work, and a total of 10 hours 25 minutes in either paid or unpaid work.

Time spent in paid work manifested a weak-to-moderate negative correlation with science achievement (−.15), with the relationship slightly stronger for males (−.19) than for females (−.11) (Table 6.12). Unpaid work is not significantly related to science achievement (either overall, or by gender). However, there is a weak negative correlation for males (−.06) and overall (−.04) for reading achievement. The total number of hours worked (paid and/or unpaid) shows a weak-to-moderate negative correlation with science achievement (−.12). The correlation is slightly stronger for males (−.15) than for females (−.08).

Table 6.12: Correlations between hours worked and mean science scores, by gender

		r	SE
Paid work	Females	**−0.107**	0.02
	Males	**−0.193**	0.02
	Overall	**−0.153**	0.02
Unpaid work	Females	0.013*	0.02
	Males	−0.036	0.02
	Overall	−0.014	0.02
Total work	Females	**−0.084**	0.02
	Males	**−0.151**	0.02
	Overall	**−0.120**	0.02

Significant correlations are shown in bold.
* The t-values for the non-significant correlations are as follows: 0.58, −1.48 and −0.80, respectively.

The Student in School

In this section, we present some data relating to students' experiences in school. The data include the relationship between achievement and variables such as grade and study programme, study practices, absenteeism, early school leaving intent, and experiences of bullying.

Grade and Study Programme

The fact that PISA is an age-based rather than a grade-based study means that the sample contains students in a number of different grades, allowing us to compare performance across grade levels. Most students (59%) who took part in PISA in Ireland were in Third year; 21% were in Transition year; 17% in Fifth year and only 3% in Second year. As in most countries, mean scores tend to increase as grade level increases (Table 6.13). Thus, the mean of 408 obtained by Second year students is considerably lower than the 499 mean obtained by Third years or the 520 obtained by Fifth years. The highest mean score (537) was obtained by Transition year students.

Table 6.13: Mean science scores of Irish students, by grade level*

	Frequencies	Science	
	%Total	Mean	SE
Second year	2.7	**408.5**	11.0
Third year	58.6	**499.3**	3.5
Transition year (Ref category)	21.2	537.1	4.3
Fifth year	17.5	**519.6**	4.3
All Available	100.0	508.3	3.2

Significant differences in bold.
* Data for two First year students who participated in PISA are not included in this table.

Table 6.14 presents data on study programme and achievement. Again, Transition year students significantly outperformed Junior Certificate and Leaving Certificate Applied students (but not students enrolled in the Leaving Certificate established or Vocational programmes). The performance of Transition year students needs to be considered in the context of factors such as their atypical ESCS composition. For example, while Ireland nationally (and students on all other study programmes in Ireland) has a mean ESCS that is below the OECD average of 0.0, the mean among Transition year students is +.22 (well above national and OECD averages). This can be contrasted with the mean ESCS of –.52 among Leaving Certificate Applied students and of –.16 among Leaving Certificate Established students.

Table 6.14: Mean science scores of Irish students, by study programme

	Frequencies	Science	
	%Total	Mean	SE
Junior Certificate	61.3	**495.1**	3.7
Transition year (Ref category)	21.2	537.1	4.3
LC Applied	1.3	**425.2**	14.9
LC Established	12.6	530.2	5.2
LC Vocational	3.6	515.8	8.2
All Available	100.0	508.3	3.2

Significant differences in bold.

Science Uptake at Junior Certificate

In Chapter 5, we described performance on the PISA science test by uptake of Junior Certificate science. Here, we consider reasons why some students did not study science at Junior Certificate. As most students did study science, data are only available for a small number of students. Furthermore, of those who did not study science, some chose not to provide a reason. That caveat aside, the main reason selected (from eight offered) was that the student did not like science (61%), followed by a perception of science as too difficult (53%) (Table 6.15). Half of those who answered indicated that they had to choose between science and another subject, while 43% felt that they didn't need science for the type of job they wanted. All other reasons (e.g., my friends were not doing science) were chosen by much smaller percentages of students. More than one in ten (11.5%) said that they did not do science because they had not been offered it as a subject choice.

Table 6.15: Percentages of Irish students reporting various reasons for not studying Junior Certificate science

(N=365)	%	SE
I don't like science	61.3	3.19
I think that science is too difficult	52.9	4.27
I had to choose between science and another subject that I wanted to take	49.7	3.06
I will not need science for the kind of job I want	42.8	2.39

Study Practices

Students were asked a number of questions about the amount of time they dedicated to the three major PISA domains, including the amount of time they spent each week in regular lessons, in after-school lessons, and in study or homework. Students not studying science at the time of the assessment were excluded from analyses relating to science. Furthermore, Table 6.16 shows only responses for Third year students (the modal grade for PISA participants in Ireland). The modal responses indicate that students spent between two and four hours a week in lessons, and less than two hours in homework or study relating to each domain (science, English, mathematics).

Table 6.16: Percentages of Irish Third year students reporting how much time they spent in science, English and mathematics lessons per week

		N	% of students				
			No time	< 2 hours a week	2 - 4 hours a week	4 - 6 hours a week	6 + hours a week
Lessons	Science	2377	4.0	15.3	64.0	15.4	1.2
	English	2611	1.7	11.0	49.6	30.7	7.1
	Mathematics	2598	1.5	9.1	47.3	34.3	7.8
Homework	Science	2381	15.1	60.1	19.4	4.3	1.1
	English	2616	10.8	52.9	26.1	7.7	2.5
	Mathematics	2606	8.9	51.5	30.1	7.1	2.4

A large minority of Third year students took out-of-school lessons, ranging from 26.5% for science to 33.9% for English, and 46.6% for mathematics. Students engaged in such lessons tended to do less well on the relevant domain than students not engaged. For example, the mean score for students not taking out-of-school science lessons was 516, significantly higher than the mean of 486 obtained by students taking lessons (Table 6.17).

Table 6.17: Mean science scores of Third year Irish science students, by uptake of out-of-school lessons

	Frequencies		Science	
	%Total	%Available	Mean	SE
No out-of-school lessons	71.5	73.5	**516.3**	3.8
Out-of-school lessons (Reference category)	25.8	26.5	486.5	4.3
Missing	2.7	0.0	**446.0**	13.8
All Available	97.3	100.0	508.4	3.4

Significant differences in bold.

Absenteeism

Students in Ireland were asked some additional questions about their school attendance. Just over half (57%) had not missed any school days in the two weeks preceding the assessment administration, while a further 32% had missed either one or two days (Table 6.18). Students who had not missed any days significantly outperformed students who had missed one or two days, three or four days, and five or more days. The largest gap was the 59-point difference between the mean science scores of students who had missed no days and of students who had missed five or more days.

Table 6.18: Mean science scores of Irish students, by absences from school (last two weeks)

	Frequencies		Science	
	%Total	%Available	Mean	SE
None (Reference category)	54.1	56.5	521.7	3.3
1 or 2	30.7	32.0	**508.6**	3.6
3 or 4	6.2	6.5	**470.3**	6.5
5 plus	4.7	4.9	**462.7**	8.1
Missing	4.3	0.0	**442.9**	10.5
All Available	95.7	100.0	511.2	3.0

Significant differences in bold.

The main reason offered for absence was that the student did not feel well, (60% of those who had been absent), followed by 11% who indicated that an appointment (e.g., a dentist) was the reason for their absence. Five percent indicated that they could not face going to school, while 3% said that they were helping or working at home.

Early School-Leaving Intent

In Ireland only, students were asked if they planned to stay in school until they had completed the Leaving Certificate. Most (90%) indicated that they planned to do so. These students obtained a significantly higher mean science achievement score than students who planned to drop out of school before completing the Leaving Certificate and those who were unsure of their plans (Table 6.19). A slightly larger percentage of females (93.7%) than males (85.7%) indicated that they definitely planned to complete Leaving Certificate, but the relationship between early school leaving intent and achievement was very similar for both males and females.

Table 6.19: Mean science scores of Irish students, by early school-leaving intent

	Frequencies		Science	
	%Total	%Available	Mean	SE
No (Reference category)	87.9	89.8	518.2	2.8
Unsure	8.2	8.3	**436.9**	7.2
Yes	1.9	1.9	**413.8**	11.2
Missing	2.1	0.0	**458.5**	13.2
All Available	97.9	100.0	509.4	3.2

Significant differences in bold.

Bullying

Students in Ireland were asked a number of questions (not included in the international version of the questionnaire) about their experiences of bullying in the school term during which PISA took place[2]. Rather than being asked to answer yes or no to whether they had ever been bullied, they were presented with a list of types of bullying and asked to indicate which they had personally experienced. Questions related to bullying by a student in their school, either inside or outside of school hours. This is a slightly broader timeframe than is normally used and may account for the large percentage of students indicating that they had been bullied by a fellow student.

Overall, 43% of students reported having experienced at least one of the forms of bullying listed, while 14% had experienced three or more forms of bullying (Table 6.20). Students who had not experienced bullying in any form obtained the highest score on the science scale (522), significantly outperforming students who had experienced three (491) or four or more (480) forms. The relationship between bullying and achievement seems to be influenced by gender. Females who experienced one type of bullying averaged 16 points fewer than females who had experienced none (507.8 versus 523.4), while the corresponding gap for males was only

[2] The questions asked were a modified version of a self-report questionnaire developed by Olweus (1993). Nick Sofroniou's help with these questions is acknowledged.

6 points (515.6 versus 521.4). Among males, achievement differences are significant only when those who had not been bullied are compared with those who experienced four or more types of bullying. For females, the difference is significant when students who had not been bullied are compared with students who experienced two or more types of bullying (one type for mathematics and reading).

Table 6.20: Mean science scores of Irish students, by number of types of bullying experienced in the current term

	Frequencies		Science	
	%Total	%Available	Mean	SE
None (Reference category)	50.6	56.6	522.4	3.3
One	17.1	19.1	511.3	4.6
Two	9.3	10.4	510.5	5.6
Three	6.0	6.7	**491.3**	5.9
Four or more	6.5	7.2	**479.6**	6.5
Missing	10.6	0.0	**461.4**	6.7
All Available	89.4	100.0	513.9	3.0

Significant differences in bold.

Student Characteristics: PISA 2000-2006

In this section, we compare data on a small number of student characteristics collected in PISA studies over the period 2000 to 2006. Many of the variables in PISA 2006 cannot be used for direct comparison, either because they were not included in earlier studies or because they had been altered in some way. For example, mean ESCS among Irish students in PISA 2006 is −0.02, but we cannot say that this is higher or lower than the Irish mean in PISA 2003 (−0.08) because the scale in each year was centred on an OECD mean of 0.0. We can only conclude that in both 2003 and 2006, the Irish mean on ESCS was slightly below the OECD mean for that year.

Table 6.21 presents some selected comparisons over time. The table is intended only as a broad indicator of how student characteristics may have changed. Each of the percentages shown has an associated measurement error. Thus, differences of a few percentage points do not necessarily mean that students at one point in time differ significantly from students at another point.

There has been a marginal drop (3%) since 2000 in the percentage of students categorised as 'native' Irish, and Ireland continues to have a smaller percentage of students categorised as immigrant than most OECD countries. The percentage of students whose parents had only a primary level education declined steadily since 2000 – falling from 12% to 3% - while the percentage with third-level qualifications almost doubled. However, some of the change may be an artefact of differences in the way questions were framed in 2000 and 2006.

There has been a slight drop (7%) in the percentage of students with four or more siblings, but no change in the percentage with 10 or fewer books in their home. Roughly one in ten Irish students had no more than 10 books in their home. However, the phrasing for the question about number of books in the home has altered slightly since 2000, meaning that the data should be interpreted with caution. The percentage of students who had no absences during the two weeks prior to the test administration remains almost unchanged since 2000.

Table 6.21 also contains some general comparisons on items relating to parent-student interaction. These items were not included in 2003. Although a 5-point scale, we have presented the percentages at the two extremes of the scale to facilitate comparison across years. As can be seen, the frequency of political or social discussions seems quite similar in 2000 and 2006 (in 2000, 10% did so several times a week, while the comparable figure in 2006 was 11%). There is a slight increase – from 26% to 35% doing so several times a week – in the frequency of discussing books, films and TV programmes with parents. The percentage of students who reported that they discussed their progress in school with their parents on several occasions a week is almost identical in 2000 and 2006. The percentage who reported eating dinner at a table with their parents several times a week dropped slightly (from 77% to 75%). Finally, the percentage of students spending time just chatting with parents on several occasions each week increased (from 62% to 65%), but again, the difference is marginal. Overall, the data in Table 6.21 indicate that many of the student characteristics investigated have proven relatively stable over time.

Table 6.21: Summary of selected student characteristics, PISA 2000-2006

		2000	2003	2006
'Native' students		97.7	96.5	94.4
Parental education: primary only		11.8	5.7	3.0
Parental education: Third level		24.5	39.9	45.9
4 or more siblings		25.3	24.5	18.5
0-10 books in the home		9.7	10.3	10.3
No absences in previous 2 weeks		57.3	60.2	56.5
Discuss political or social issues	Never/hardly ever	31.9	-	34.0
	Several times a week	10.0	-	11.3
Discuss books, films, TV	Never/hardly ever	13.2	-	12.3
	Several times a week	25.7	-	34.7
Discuss school progress	Never/hardly ever	2.7	-	4.9
	Several times a week	47.9	-	48.0
Eat dinner at table	Never/hardly ever	4.3	-	6.1
	Several times a week	77.1	-	74.5
Spend time just chatting	Never/hardly ever	4.6	-	5.8
	Several times a week	61.6	-	64.7

Summary

This chapter outlined the relationship between a variety of student characteristics and achievement. As the three PISA assessment domains typically have similar relationships with explanatory variables, the analyses largely focused on associations with scientific literacy. The percentage of students not classified as native (6%) is larger than the 2% who spoke a language other than English or Irish at home. However, only language related significantly to achievement (those not speaking

English or Gaeilge performed significantly poorer). Larger family size was associated with poorer achievement, and the highest mean scores on each domain were obtained by students with one sibling. There were clear relationships between achievement and parental education levels, and scores on the ISEI and ESCS scales (both measure of socioeconomic status). For example, there was a difference of approximately 30 points between the mean scores of the low and medium ISEI categories, and between the means of the medium and high categories.

Ireland ranked 21st of the 30 OECD countries on an index of availability of educational resources in the home and 26th of the 30 OECD countries on an index of cultural possessions in the home. Both indices were positively related to achievement, meaning (for example) that greater availability of resources was associated with better performance. Irish students were above the OECD average on almost all 'affluence indicators' (household possessions thought to indicate wealth, such as mobile phones, cars and dishwashers). While most such indicators were positively associated with achievement, indicators related to television were negatively linked to achievement. For example, students with a premium cable TV package at home were significantly outperformed by students without such a package.

Students (in Ireland only) were asked how often they engaged in a range of activities with their parents – e.g., discussing with their parents how they were getting on in school, or just chatting. Frequency of engagement in any of the activities tended to be associated with science scores, with the relationship most pronounced for discussing politics and social issues. Almost two-thirds of Irish students engaged in at least some paid work during school term, and there was a weak-to-moderate negative correlation between hours worked and science achievement, with the relationship slightly stronger for males than for females.

Most students who took part on PISA in Ireland were in Third year. As in most countries, mean scores tended to increase as grade level increased. Highest scores were obtained by Transition year students, but this is likely to be accounted for by their atypical socioeconomic composition. Just under half of students had missed school days in the two weeks preceding the assessment administration, and these obtained lower mean achievement scores than students who had attended all days in the same period. Overall, 43% of students reported they had experienced some form of bullying (e.g., physical abuse or being excluded from conversations) in the school term in which PISA took place. Students who had not experienced bullying in any form obtained the highest mean achievement score. Analyses of variables amenable to comparison over time reveal that there has been a slight drop since 2000 in the percentage of students categorised as 'native' Irish and in average family size, and a notable improvement in parental educational attainment. There has been no discernible change in most other student characteristics (including number of books in the home, frequency of parental interaction, and absenteeism rates).

Chapter 7
Students' Attitudes to and Engagement in Science

The definition of scientific literacy in PISA 2006 includes a reference to students' 'willingness to engage in science-related issues and with the ideas of science, as a reflective citizen' (OECD, 2006, p. 20). To assess this, PISA examined students' attitudes towards, and engagement in, science in two ways:

- through items on the Student Questionnaire
- through items embedded in the student test booklets.

Inset 7.1: How to Interpret Scores on Attitudinal Indices and Scales

Students' attitudes to science can be examined by considering responses to individual questionnaire items as well as scores on indices and scales based on clusters of related items. We report performance on:

- *items* in terms of percentage of students offering a particular response.
- *indices* derived from the student questionnaire with reference to an OECD average score of 0.0 (notionally, the score achieved by the average student in the OECD area) and a standard deviation of 1 (meaning that, across OECD countries, 68% of scores lie between +1 and –1). A national mean of 1.5 is one half of a standard deviation above the OECD average, while a mean of –1.0 is a standard deviation below.
- *scales* based on clusters of attitudinal items embedded in the PISA science test, with an OECD average of 500, and a standard deviation of 100.

It should be noted that just three of the measures of students' attitudes – *awareness of environmental issues, general value of science*, and *self-efficacy in science* – lend themselves to cross-country comparisons. These measures relate to science achievement in a consistent way, both within countries and between OECD countries (OECD, 2007b). The remaining measures, including scales derived from attitudinal items embedded in students' test booklets, are best interpreted within countries only, as they do not relate to achievement in a consistent manner between countries.

This chapter divides the PISA attitudinal and engagement measures into three sets: indices that are cross-culturally comparable; indices that are best interpreted at national level only; and scales based on attitudinal items embedded in the science test (Table 7.1). After describing the indices and scales in each category, correlations among indices and between these and student achievement are considered. The chapter concludes with an analysis of students' aspirations for science-related careers.

Table 7.1: Division of attitudinal item clusters into areas and categories

General area	Cross-nationally comparable	Nationally comparable	Based on embedded items
Support for scientific enquiry	General value of science	Personal value of science	Support for scientific enquiry
Self-belief as science learners	Self-efficacy in science	Self-concept in science	-----
Interest in science	-----	General interest in science; Enjoyment of science; Instrum. motivation to learn science; Future-orientated motiv. to learn science; Participation in science-related activities	Interest in learning about science topics
Responsibility towards resources and environments	Awareness of environmental issues	Concern for environmental issues; Responsibility for sustainable dev't; Optimism re environmental issues.	-----

Cross-Nationally Comparable Indices

In this section, three scales that are cross-nationally comparable are described: *awareness of environmental issues, general value of science*, and *self-efficacy in science*. As in Chapters 3 and 4, the five highest-scoring countries, and the five comparison countries of Denmark, Germany, New Zealand, Poland, USA, and the UK (as data for the constituent parts are missing for some variables) are shown on the tables in this section.

Awareness of Environmental Issues

Students' *awareness of environmental issues* was assessed by asking them to indicate their familiarity with five issues. More students in Ireland than on average across OECD countries indicated at least some familiarity with four of the five target topics (Table 7.2). The exception was use of genetically modified organisms, about which just 26% of students in Ireland reported some familiarity, compared with an OECD average of 35%.

Table 7.2: Percentages of students indicating they are 'familiar with' or 'know something about' selected environmental issues (Ireland and OECD average)

Students are ' familiar with' or' know something about' …	IRL	OECD
…the consequences of clearing forests for other land use	81.8%	72.7%
…acid rain	82.7%	59.9%
…the increase of greenhouse gases in the atmosphere	75.0%	58.4%
…nuclear waste	63.5%	52.7%
…the use of genetically modified organisms	26.0%	35.0%

The data (questionnaire items) were scaled to an OECD average of 0.0 and a standard deviation of 1. After partner country Chinese Taipei, OECD countries Ireland (0.38) and Poland (0.37) had the highest mean scores on the *awareness of environmental issues* index (Table 7.3). In contrast, New Zealand and Denmark had mean scores that were below the OECD average, indicating that students in those countries reported lower levels of familiarity with several environmental issues. In almost all OECD countries, male students had a significantly higher mean score on the index than females. In Ireland, the difference in favour of males was 0.12 points, while the OECD average difference was 0.18.

Across countries in PISA 2006, there was a consistent relationship between *awareness of environmental issues* and achievement on the overall science scale. In Ireland, there was a significant difference of 104 points (over one standard deviation) on the overall science scale between mean scores of students at the top and bottom quarters of the index (Table 7.3). Also in Ireland, there is a 41-point increase in science achievement associated with an increase of one standard deviation on the index. The corresponding OECD average is 44 points. Even in countries with a low relative score on *awareness of environmental issues*, there is a significant difference in science achievement between students in the top and bottom quarters on the index.

In all countries in PISA, students with higher ESCS (Economic Social and Cultural Status – see Chapter 6) scores tended to report higher *awareness of environmental issues*. In Ireland, a medium-sized effect (0.63) was found for the difference between students in the top and bottom quarters of the ESCS scale (OECD, 2007c, Table 3.17). The corresponding OECD average effect size was 0.66.

Table 7.3: Mean scores of high-scoring and comparison countries on awareness of environmental issues index, mean scores on science achievement of students in the top and bottom quarter of the index, and association between the index and science achievement

	Awareness of environmental issues index				Overall science scale			
	Mean scores			Diff: Males - Females	Mean scores		Diff: Top - Bottom	Assoc w/ index*
	All	Males	Females		Bottom Q Index	Top Q Index		
Chinese Taipei	0.46	0.51	0.40	**0.11**	465.3	579.6	**114.3**	48.4
Ireland	0.38	0.44	0.32	**0.12**	450.4	554.8	**104.5**	41.4
Poland	0.37	0.38	0.37	0.01	442.0	554.7	**112.8**	41.6
Hong Kong-Ch	0.34	0.38	0.31	**0.07**	483.3	591.0	**107.7**	52.0
Croatia	0.32	0.32	0.33	0.00	434.0	543.7	**109.7**	45.7
UK	0.25	0.40	0.11	**0.29**	441.2	582.9	**141.7**	50.4
Germany	0.15	0.31	−0.01	**0.32**	451.5	577.0	**125.5**	43.9
US	0.01	0.11	−0.10	**0.21**	421.9	545.2	**123.3**	40.8
OECD	0.00	0.09	−0.09	**0.18**	439.0	553.6	**114.6**	44.0
New Zealand	−0.12	−0.02	−0.21	**0.19**	453.2	597.6	**144.1**	54.5
Denmark	−0.21	−0.06	−0.35	**0.29**	431.0	557.8	**126.8**	46.7

Statistically significant mean score differences (p. < .05) are in bold.

*Indicates increase in science achievement corresponding with an increase of one standard deviation on the index. All associations are statistically significant (p. < .05).

Source: OECD (2007c), Tables 3.16.

General Value of Science

General value of science was assessed by asking students to indicate their level of agreement with five statements relating to potential benefits of science. As in other OECD countries, most students in Ireland expressed agreement with the view that science is important for understanding the natural world, and that advances in science and technology usually improve people's living conditions (Table 7.4). On the other hand, one-quarter of students in Ireland, and one-third across OECD countries did not agree with the view that advances in science and technology usually bring social benefits.

Table 7.4: Percentages of students indicating they 'agree' or 'strongly agree' with various statements representing general value of science (Ireland and OECD average)

Students 'agree' or 'strongly agree' that…	IRL	OECD
…science is important for helping us to understand the natural world	94.2%	92.9%
…advances in science and technology usually improve people's living conditions	92.4%	91.6%
…science is valuable to society	85.7%	86.9%
…advances in science and technology usually help to improve the economy	84.5%	80.0%
…advances in science and technology usually bring social benefits	66.6%	75.0%

An index of *general value of science* was developed using all five items. The highest-scoring countries on the index were partner countries Thailand and Chinese Taipei (Table 7.5). Care needs to be taken in interpreting these data since, unlike most OECD countries, partner countries such as Thailand and Tunisia do not have the high levels of enrolment in secondary schooling that are found in OECD countries (OECD, 2007b, Table A10.1b), and hence participants in PISA do not represent the population of 15-year olds.

Table 7.5: Mean scores of high-scoring and comparison countries on the general value of science index, mean scores on overall science of students in the top and bottom quarters of the index, and association between the index and overall science

	General value of science index				Overall science scale			
	Mean scores			Diff: Males - Females	Mean scores		Diff: Top - Bottom	Assoc w/ Index*
	All	Males	Females		Bottom Q Index	Top Q Index		
Thailand	0.77	0.66	0.86	**−0.20**	392.8	445.0	**52.2**	22.2
Chinese Taipei	0.72	0.80	0.63	**0.17**	502.5	550.3	**47.8**	17.8
Tunisia	0.70	0.66	0.75	**−0.09**	356.8	411.6	**54.8**	21.7
Jordan	0.60	0.49	0.70	**−0.21**	384.2	449.6	**65.4**	24.6
Chile	0.58	0.66	0.48	**0.19**	414.4	462.2	**47.8**	17.9
Poland	0.22	0.22	0.23	−0.01	463.6	529.3	**65.7**	27.6
US	0.15	0.22	0.07	**0.15**	448.8	528.8	**80.0**	29.9
Ireland	0.02	0.07	−0.02	**0.09**	464.6	545.6	**81.1**	30.9
OECD	0.00	0.06	−0.06	**0.12**	463.9	533.2	**69.3**	28.1
Germany	−0.10	0.20	−0.22	**0.25**	482.8	550.4	**67.7**	26.9
New Zealand	−0.13	−0.08	−0.19	**0.11**	485.5	573.8	**88.3**	35.4
UK	−0.16	−0.03	−0.28	**0.26**	463.4	562.6	**99.3**	39.2
Denmark	−0.27	−0.22	−0.32	**0.11**	472.5	530.3	**57.8**	27.7

Differences that are statistically significant (p. < 0.05) are in bold.

*Indicates increase in science achievement corresponding with an increase of one standard deviation on the *General value of science* index. All associations are statistically significant (p. < .05).

Source: OECD (2007c), Table 3.5.

Ireland's mean score of 0.02 on *general value of science* was close to the OECD average of 0.0. New Zealand (−0.13) and Denmark (−0.27) were among the countries with a score on the index that was below the OECD average. While females scored higher than males in some partner countries, males in OECD countries typically had a significantly higher mean score than females. An exception is Poland, where the difference is not statistically significant.

The differences in mean science scores between students in the top and bottom quarters of the index were greater in OECD countries than in partner countries, indicating a stronger relationship between *general value of science* and overall science performance. In Ireland, the difference in mean scores was 81 points, which was greater than the OECD average difference (69). Also in Ireland, there was an increase of 31 points on the science achievement test associated with an increase of one standard deviation on the index. This is marginally greater than the OECD average increase of 28 points.

Across OECD countries, students with scores in the top quarter of the ESCS index had a higher mean score than students in the bottom quarter. In Ireland, the effect size associated with the difference (0.61) is in the medium range (OECD, 2007c, Table 3.22). The corresponding OECD effect size was 0.46. Hence, there is a somewhat stronger association between socioeconomic status and *value of science* among students in Ireland than on average across OECD countries.

Self-Efficacy in Science

Students' self-efficacy in science, or their confidence in their ability to perform science tasks, was measured by asking them to indicate how much effort they would expend in solving each of eight tasks. More students in Ireland (81%) than on average across OECD countries (76%) said they could explain why earthquakes occur, perhaps reflecting their confidence in relation to geography as well as science (Table 7.6). In contrast, fewer students in Ireland (41%) than across OECD countries (51%) said they could discuss how new evidence could lead to change in understanding about the possibility of life on Mars. This may reflect the fact that most of the other topics are covered (to a greater or lesser extent) in the rJCSS, whereas life on Mars is not.

Table 7.6: Percentages of students indicating they could 'easily' or 'with a bit of effort' perform various tasks (Ireland and OECD average)

Students could 'easily', or 'with a bit of effort' …	IRL	OECD
…explain why earthquakes occur more frequently in some areas than in others	81.3%	76.2%
…recognise the science question that underlies a newspaper report on a health issue	68.2%	73.1%
…interpret the scientific information provided on the labelling of food items	63.7%	64.4%
…predict how changes to an environment will affect the survival of a certain species	63.2%	64.4%
…identify the science question associated with disposal of waste	68.9%	61.9%
…describe the role of antibiotics in the treatment of disease	55.0%	58.8%
…identify the better of two explanations for the formation of acid rain	64.5%	57.8%
…discuss how new evidence can lead you to change your understanding about the possibility of life on Mars	41.1%	50.7%

An index of *self-efficacy in science* was established using student responses to the eight tasks. The highest mean score on the index (0.26) was achieved by students in Poland, while Ireland's mean score (0.01) was very close to the OECD average of 0.0 (Table 7.7). A number of high-scoring countries on the PISA overall science scale (e.g., New Zealand, Japan, and Korea) scored below the OECD average on *self-efficacy in science*, suggesting that although students in those countries did well in science, they did not view themselves as confident in performing science-related tasks. In contrast, students in the United States had a high mean score for *self-efficacy in science*, despite scoring significantly below the OECD average on the overall science scale. Finland, the highest-scoring country on the PISA overall science scale, had a mean score on the index (0.02) that was close to the OECD average value.

Among the countries shown in Table 7.7, males generally had a higher mean score on *self-efficacy* than females. Exceptions were Jordan, where females had a significantly higher mean score, and Poland, where females did better than males, but not to a significant extent. In Ireland, the difference in favour of males was 0.14 points, which is marginally greater than the OECD average difference of 0.12.

Table 7.7: Mean scores of high-scoring and comparison countries on the self-efficacy in science index, mean scores on overall science of students in the top and bottom quarter of the index, and association between the index and overall science

	Self-efficacy in science index				Overall science scale			
	Mean scores			Diff: Males - Females	Mean scores		Diff: Top - Bottom	Assoc w/ Index*
	All	Males	Females		Bottom Q Index	Top Q Index		
Poland	0.26	0.24	0.28	−0.04	445.6	553.4	**108.8**	42.7
US	0.22	0.32	0.12	**0.20**	436.4	546.7	**110.3**	36.0
Canada	0.21	0.30	0.13	**0.17**	480.7	589.3	**108.6**	39.0
Jordan	0.21	0.12	0.31	**−0.19**	395.9	447.1	**51.2**	17.5
Portugal	0.21	0.23	0.19	0.04	434.3	516.5	**82.2**	31.7
UK	0.19	0.32	0.05	**0.27**	443.3	591.7	**148.4**	52.6
Germany	0.06	0.13	−0.01	**0.14**	466.0	579.0	**113.0**	44.1
Ireland	0.01	0.08	−0.06	**0.14**	454.6	564.9	**110.3**	40.3
OECD	0.00	0.06	−0.06	**0.12**	452.2	551.4	**99.2**	37.7
New Zealand	−0.02	0.05	−0.09	**0.14**	464.4	612.1	**147.7**	53.2
Denmark	−0.08	0.04	−0.20	**0.24**	443.8	556.5	**112.7**	41.4

Mean scores that are statistically significant (p. < 0.05) are in bold.

*Indicates increase in science achievement corresponding with an increase of one standard deviation on the self-efficacy in science index. All associations are statistically significant (p. < .05).

Source: OECD (2007c), Tables 3.3, 3.4.

Of the countries shown in Table 7.7, the largest mean score differences on the overall science scale between students in the top and bottom quarters of *self-efficacy in science* are in the United Kingdom and New Zealand (both 148 scale score points). In Ireland, the difference is 110 points, which is above the OECD average difference of 99 points. In Ireland, there was an increase of 40 points in science achievement associated with a one standard deviation increase on the self-efficacy index. This was slightly greater than the OECD average (37 points).

Across OECD countries, students with scores in the top quarter of the ESCS index had a higher mean score on the self-efficacy index than students in the bottom quarter. The effect size in Ireland (0.75) was at the high end of the medium range (OECD, 2007c, Table 3.22). The corresponding OECD average was 0.64, indicating a somewhat stronger association in Ireland between *self-efficacy in science* and socioeconomic and cultural status, compared with the OECD average.

National Attitudinal Indices

This section describes attitude indices that, according to the OECD, do not lend themselves to comparison across countries, as their relationship with achievement is inconsistent. However, we can compare responses to component items (i.e., the questionnaire items) across countries. As with the cross-nationally comparable indices, each national attitudinal index was scaled to an OECD mean of 0.0 and a standard deviation of 1.0. Here, groups of indices are described in terms of key constituent elements (questionnaire items), gender differences, and associations with achievement among students in Ireland. In addition, each index is considered with respect to its association with student socioeconomic and cultural status (ESCS).

Interest in Science

Table 7.8 summarises some of the items underlying indices of interest in science, including *general interest in science*, *instrumental motivation to learn science*, *enjoyment of science*, and *engagement in science-related activities*. Items that made up the index of *general interest in science* asked students about their interest in specific areas of science. For example, 77% of students in Ireland and 68% across OECD countries indicated high or medium interest in human biology (Table 7.8). On the other hand, just 41% in Ireland and 49% across OECD counties indicated high or medium interest in topics in physics. Fewer students in Ireland (44%) than on average across OECD countries (50%) expressed an interest in chemistry.

Table 7.8: Examples of component items contributing to national attitudinal indices of interest in science

Index (Scale)	Sample items	% IRL	% OECD
General interest in science (High / medium interest)	Human biology	76.9	68.4
	Topics in chemistry	43.5	50.4
	Topics in physics	40.8	48.9
	The biology of plants	55.2	47.3
Instrumental motivation to learn science (Agree / strongly agree)	I study school science because it is useful to me	73.0	66.7
	Studying school science subjects is worthwhile because what I learn will improve my career prospects	68.3	61.5
	I will learn many things in my school science subjects that will help me get a job	66.7	56.2
Enjoyment of science (Agree / strongly agree)	I enjoy acquiring new knowledge in science	67.9	67.3
	I am interested in learning about science	64.0	63.1
	I like reading about science	44.8	50.3
	I am happy doing science problems	39.3	43.0
Engagement in science-related activities (Very often / regularly)	Watch TV programmes about science	17.6	21.0
	Read science magazines or science articles in papers	10.8	20.3
	Visit websites about science topics	8.7	12.7
Future-orientated motiv. to learn science (Agree / strongly agree)	I would like to work in a career involving science	41.4	37.4
	I would like to study science after secondary school	35.9	30.8

Source: OECD (2007b), Figures 3.8, 3.10, 3.12, 3.13 and 3.16

Items that contributed to *instrumental motivation to learn science* asked students to indicate their agreement with statements linked to the material benefits of learning science. For example, 73% of students in Ireland, and 67% across OECD countries agreed or strongly agreed with the statement that 'I study school science because it is useful to me'. More students in Ireland than on average across OECD countries also endorsed statements about the value of school science to them in improving their career prospects (68% versus 62%), and in getting a job (67% versus 56%).

Items underpinning the index of *enjoyment of science* asked students to indicate their agreement with statements such as 'I enjoy acquiring new knowledge in science' (68% of students in Ireland, and 67% across OECD countries agreed or strongly agreed) and 'I am interested in learning about science' (64% and 63% respectively). Relatively fewer students reported that they were 'happy doing science problems' (Ireland, 39%; OECD, 43%).

In general, students in Ireland reported low levels of involvement in the activities contributing to the index of *engagement in science-related activities.* For example, 11% of students in Ireland, but 20% across OECD countries, reported that they regularly or very often 'read science magazines or science newspaper articles'. Only students in Japan and the United Kingdom (8% in both countries) reported reading science articles less frequently. Similarly, students in Ireland were less likely to report visiting websites about science topics (8%), than on average across OECD countries (13%).

A somewhat greater percentage of students in Ireland than on average across OECD countries agreed or strongly agreed with statements underpinning the *future-orientated motivation to learn science* index. For example, 41% of students in Ireland, and 37% across OECD countries, expressed these levels of agreement with the statement, 'I would like to work in a career involving science'. Thirty-six percent of students in Ireland and 31% across OECD countries agreed that they would like to study science after secondary school.

Female students in Ireland had higher scores than male students on four of the five national *interest in science* indices (Table 7.9). Three differences are statistically significant, with the largest difference (one-quarter of a standard deviation) on *instrumental motivation to learn science*. Male students had a significantly higher mean score than females on one index, *engagement in science-related activities.*

Table 7.9: Mean scores overall and by gender, and gender differences on national interest in science indices

	Mean scores			Diff: Male - Female	Signif. higher score
	All	Males	Females		
General interest in science	−0.14	−0.19	−0.10	**−0.09**	Female
Instrumental motivation to learn science	0.15	0.04	0.27	**−0.23**	Female
Enjoyment of science	−0.18	−0.21	−0.15	−0.06	---
Engagement in science-related activities	−0.43	−0.34	−0.52	**0.17**	Male
Future-orientated motivation to learn science	−0.05	−0.10	0.0	**−0.09**	Female

For each of the interest in science indices, students in the top quarter of the index had a mean score on the overall science scale that was significantly higher than the mean score of students in the bottom quarter (Table 7.10). The difference in scale scores points in science approached 100 points (an international standard deviation) for the *enjoyment of science* scale. Table 7.10 also shows, for each index, the expected change in overall science performance corresponding to an increase of one standard deviation in each index. Changes range for 25 points (*instrumental motivation to learn science* and *engagement in science-related activities*) to 37 points (*enjoyment of science*).

Table 7.10: Mean scores on the overall science scale of students in the top and bottom quarter of each national interest in science index, and association between each index and overall science achievement

	Mean science score		Diff: Top - Bottom	Assoc w/ Index*
	Bottom Q Index	Top Q Index		
General interest in science	467.7	542.2	**74.5**	29.1
Instrumental motivation to learn science	479.8	549.6	**68.9**	24.8
Enjoyment of science	461.4	556.8	**95.4**	36.8
Engagement in science-related activities	471.7	540.4	**68.7**	24.8
Future-orientated motivation to learn science	474.1	553.8	**79.7**	28.6

*Indicates increase in science achievement corresponding with an increase of one standard deviation on the index. All associations are statistically significant (p. < .05).

Responsibility towards Resources and Environments

A second set of indices describes students' responsibility towards resources and the environment. The set includes *concern for environmental resources*, *optimism regarding environmental issues*, and *responsibility for sustainable development*. Some of the items underlying these indices are described in Table 7.11. Students generally reported high levels of *concern for environmental issues*, with 89% in Ireland and 92% across OECD countries saying that air pollution represented a serious issue for themselves or for people in their country. Fewer students in Ireland (67%) than across OECD countries (76%) expressed concerns about water shortages, perhaps reflecting a perception among some students of an abundance of water in Ireland.

Items underlying the scale *optimism regarding environmental issues* asked students if problems in relation to a variety of environmental issues would improve over the next 20 years. Students were generally pessimistic. For example, only 26% of students in Ireland and 21% across OECD countries felt that problems in relation to energy shortages would improve, while roughly the same percentages in Ireland (17%) and on average across OECD countries (15%) were optimistic that issues around disposal of nuclear waste would be resolved.

Table 7.11: Examples of component items contributing to national attitudinal indices relating to responsibility towards resources and environments

Index (Scale)	Sample items	% IRL	% OECD
Concern for environmental issues (Serious concern for self or other people in their country)	Air pollution	89.1	92.5
	Extinction of plants and animals	74.5	84.4
	Energy shortages	79.0	82.2
	Nuclear waste	73.6	78.0
	Water shortages	67.0	76.1
Optimism regarding environmental issues (Will improve over next 20 years)	Energy shortages	25.6	21.2
	Water shortages	26.9	18.1
	Air pollution	19.5	16.3
	Nuclear waste	17.3	15.3
	Extinction of plants and animals	15.6	13.7
Responsibility for sustainable development (Agree/strongly agree)	Industries should be required to prove that they can safely dispose of waste materials	93.8	92.3
	I am in favour of laws that regulate factory emissions, even if this would increase the price of products	60.8	69.2

Source: OECD (2007b), Figures 3.19-3.21.

Responsibility for sustainable development examined students' attitudes to strategies for such development. For example, 94% of students in Ireland, and 92% across OECD countries agreed or strongly agreed that 'industries should be required to prove that they can safely dispose of waste', while 61% in Ireland and 69% across OECD countries supported the statement, 'I am in favour of laws that regulate factory emissions, even if this would increase the price'. Hence, students seem less supportive of initiatives that would cost them more.

Female students in Ireland had higher scores than male students on *level of concern for environmental issues*, *responsibility for sustainable development,* and *personal value of science* (Table 7.12). Males had a significantly higher mean score on *optimism regarding scientific issues*. Differences were all in the region of one-fifth of a standard deviation.

Table 7.12: Mean scores overall and by gender, and gender differences on national attitudinal indices

	Mean scores			Diff: Male - Female	Signif. higher score
	All	Males	Females		
Level of concern for environmental issues	−0.26	−0.37	−0.16	**−0.20**	Female
Optimism regarding environmental issues	0.12	0.24	0.01	**0.23**	Male
Responsibility for sustainable development	−0.01	−0.10	0.08	**−0.18**	Female

Significant differences shown in bold.

For the *responsibility for sustainable development* scale, students in the top quarter had a mean score on overall science that was significantly higher than that of students in the bottom quarter (Table 7.13). For the *level of concern for environmental issues* index, there was no difference in overall science achievement between those scoring in the top and bottom quarters of the index. Students in the bottom quarter on the *optimism regarding environmental issues* index achieved a mean science score that was significantly higher than students in the top quarter, indicating a negative association between optimism and science achievement (i.e., those most optimistic did least well, and vice versa).

Table 7.13 also shows, for each index, the expected change in overall science performance corresponding to an increase of one standard deviation in each index. Changes range from –17 points (*optimism regarding environmental issues*) to 37 points *(enjoyment of science*). The negative association between optimism regarding environmental issues and overall science performance indicates that lower-achieving students in science tended to be more optimistic than higher-achieving students.

Table 7.13: Mean scores on the overall science scale of students in the top and bottom quarter of each national index of responsibility towards resources and environments, and associations between index and overall science achievement

	Mean science score		Diff: Top - Bottom	Assoc w/ Index*
	Bottom Q Index	Top Q Index		
Responsibility for sustainable development	467.2	547.0	**79.8**	32.5
Level of concern for environmental issues	507.8	509.9	2.1	3.3
Optimism regarding environmental issues	526.8	485.8	**−41.0**	−17.3

Significant differences in bold.

*Indicates increase in science achievement corresponding with an increase of one standard deviation on the index. All associations are statistically significant (p. < .05).

Self-Concept in Science and Personal Value of Science

Additional national attitudinal indices related to *self-concept in science* and *personal value of science*. Example items underpinning these indices are shown in Table 7.14. The index of *self-concept in science* asked students about their general performance in science. For example, in Ireland 62% of students said they agreed or strongly agreed with the statement, 'I can usually give good answers to test questions on school science topics'. The corresponding OECD average percentage was 65. The items associated with this scale are somewhat more general than those used to measure *self-efficacy in science* (one of the cross-nationally comparable indices), since they relate to general performance rather than performance on specific tasks.

The index *personal value of science* was based on students' level of agreement with statements such as 'I will use science in many ways when I am an adult.' Sixty-one percent of students in Ireland and 64% across OECD countries agreed or strongly agreed with this statement.

Table 7.14: Examples of component items contributing to national attitudinal indices of self-concept in science and personal value of science

Index	Sample items	% IRL	% OECD
Self-concept in science (Agree / strongly agree)	I can usually give good answers to test questions on school science topics	62.4	64.8
	When I am being taught school science, I understand the concepts very well	56.3	59.0
	Learning advanced school science topics would be very easy for me	37.3	47.3
Personal value of science (Agree/ strongly agree)	I find that science helps me understand things around me	75.4	74.9
	I will use science in many ways when I am an adult	60.8	63.8
	When I leave school, there will be many opportunities for me to use science	63.0	58.9

Source: OECD (2007b), Figures 3.4, 3.6, and 3.13.

Female students in Ireland had a higher mean score than male students on *personal value of science* (Table 7.15). On the other hand, male students had a higher mean score on *self-concept in science* (males also had a higher mean on the *self-efficacy* index described earlier).

Table 7.15: Mean scores overall and by gender, and gender differences on self-concept in science and personal value of science

	Mean scores			Diff: Male - Female	Signif. higher score
	All	Males	Females		
Self-concept in science	−0.13	−0.09	−0.17	**0.07**	Male
Personal value of science	0.00	−0.04	0.04	**−0.08**	Female

Significant differences shown in bold.

The difference in science performance between students in the top and bottom quarters of the *self-concept in science* index approached one international standard deviation (Table 7.16). The difference between students in the top and bottom quarters of *personal value of science* was also large (almost nine-tenths of an international standard deviation). Table 7.16 also shows, for each index, the expected change in overall science corresponding to a one-standard deviation increase in the index. There is a 30-point increase for personal value of science, and a 35-point increase for self-concept in science.

Table 7.16: Mean scores on the overall science scale of students in the top and bottom quarter of the self-concept in science and personal value of science indices, and associations between the indices and overall science achievement

	Mean science score		Diff: Top - Bottom	Assoc w/ Index*
	Bottom Q Index	Top Q Index		
Self concept in science	471.1	566.4	**95.3**	35.0
Personal value of science	465.7	552.6	**86.9**	29.6

Significant differences in bold.

*Indicates increase in science achievement corresponding with an increase of one standard deviation on the index. All associations are statistically significant (p. < .05).

Socioeconomic Status and National Attitudinal Indices

As with the cross-nationally comparable indices, we can look at associations between national indices and socioeconomic status (ESCS). Table 7.17 shows the effect sizes for the differences between the top and bottom quarters of the ESCS scale on each national attitudinal index. Effect sizes between 0.2 and 0.5 can be considered small, those between 0.5 and 0.8 medium, and those greater than 0.8 large.

Table 7.17: Effect sizes for mean score differences on national attitudinal indices for students at the top and bottom quarters of the PISA ESCS scale

Attitudinal Index	Effect Size (Top - Bottom Q of Index)	SE of Effect Size
Enjoyment of science	**0.53**	0.19
Future-orientated motivation to learn science	**0.44**	0.17
General interest in science	**0.57**	0.18
Instrumental motivation to learn science	**0.46**	0.15
Self concept in science	**0.56**	0.20
Personal value of science	**0.65**	0.23
Responsibility for sustainable development	**0.48**	0.17
Engagement in science-related activities	**0.49**	0.18
Level of concern for environmental issues	0.00	0.04
Optimism regarding environmental issues	**−0.15**	0.08

Significant effect sizes in bold.

Most differences in Table 7.17 are in the medium category, meaning that there are moderate relationships between students' socioeconomic and cultural status and their scores on the indices. The largest effect (and hence the strongest impact of ESCS) is for *personal value of science*. There is no difference between students with high and low ESCS scores on *level of concern for environmental issues*. In the case of *optimism regarding environmental issues*, the effect size is greater for students with low ESCS scores, than for students with high scores. This indicates that high ESCS students tend to have lower scores on the *optimism regarding environmental issues* scale than low ESCS students. However, the effect size is just −0.15, and, although statistically significant, can be considered small.

Scales Based on Embedded Attitudinal Items

Two attitudinal scales in PISA 2006 – *interest in learning about science topics*, and *support for scientific inquiry* – are based on items embedded in the science test. Again, because associations with achievement are inconsistent between countries, these scales are considered for Ireland only. Components of the scales, gender differences, and associations with overall science (correlations) are described in this section.

Interest in Learning about Science Topics

Students who responded to the units entitled *Acid Rain* and *Genetically Modified Crops* were asked to indicate their level of interest in learning about topics associated with these units. (Both units have been released by the OECD and are available on *www.erc.ie/pisa.*). Students in Ireland were more interested in knowing which human activities contributed to acid rain (66%), and in learning about technologies that minimise emissions of gases that cause acid rain (57%), than in learning about the processes by which plants are genetically modified (33%), or about the difference between cross-breeding and genetic modification (39%) (Table 7.18).

Table 7.18: Percentages of students reporting that they had high or medium interest in learning more about specific science topics (Ireland and OECD average)

	Students have 'high' or 'medium' interest in …	IRL	OECD
Acid Rain	…knowing which human activities contribute most to acid rain	66.3%	61.6%
	…learning more about technologies that minimise the emission of gases that cause acid rain	57.3%	58.7%
GM Crops	…learning about the process by which plants are genetically modified	33.2%	46.0%
	…understanding better the difference between plant cross-breeding and genetic modification	39.1%	47.1%

Using six such items, a scale with an OECD mean of 500 and a standard deviation of 100 was constructed. The mean score for Ireland on the resulting *interest in learning science topics* scale was 481.2 (SE =1.90). This is significantly lower than the OECD average (500.0 SE = 0.35). In Ireland, male students had a mean score (484.2, SE = 2.33) that was greater that that of females (478.3, SE = 2.73), but not to a significant extent. The OECD average difference, 2 scale points in favour of male students, is statistically significant (OECD, 2007c, Table 3.1).

Support for Scientific Enquiry

Students who responded to the *Acid Rain*, *Grand Canyon,* and *Mary Montagu* test units were asked to indicate their level of agreement with several statements suggesting additional scientific inquiry or research. The vast majority of students in Ireland and across OECD countries were supportive of additional scientific enquiry (Table 7.19).

Table 7.19: Percentages of students who 'agreed' or 'strongly agreed' with statements suggesting additional enquiry or research (Ireland and OECD average)

	Students 'agree' or 'strongly agree' that …	IRL	OECD
Acid Rain	…statements based on the causes of acid rain should be based on scientific research	84.9%	85.1%
Grand Canyon	…the systematic study of fossils is important	85.8%	86.2%
Mary Montagu	…I am in favour of research to develop vaccines for new strains of influenza	95.7%	94.4%

Using 8 such items, a scale for *support of scientific enquiry*, also with an OECD mean of 500 (SE = 0.40) and a standard deviation of 100, was constructed. The mean score of students in Ireland on the scale was 484.3 (SE = 1.95), which is significantly below the OECD average. Male students in Ireland had a mean score (488.0, SE = 2.32) that was significantly higher than that of females (480.7, SE = 2.6), indicating stronger support for scientific inquiry among males. The OECD average difference of −0.5 points on the scale in favour of females is not statistically significant (OECD, 2007c, Table 3.2).

How Science Attitudes Related to Each Other

Almost all of the attitudinal indices and scales reviewed in earlier sections of this chapter have significant associations with overall science achievement. However, the variables are also associated with one another. Tables 7.20 to 7.23 show correlations among attitudinal variables for students in Ireland, as well as correlations between attitudinal variables and overall science performance. The attitudinal scales/indices are divided into four clusters: those related to support for scientific inquiry, self-belief as science learners, interest in science, and responsibility towards resources and the environment. In Ireland, the correlation between *general value of science* and *personal value of science* is 0.63 (Table 7.20). The corresponding OECD average correlation is 0.61. This suggests that, in Ireland and across OECD countries, a common factor underlies the support for science measures used in PISA.

Table 7.20: Correlations among indices/scales of support for science, and correlations between indices/scales and overall science performance

	Support for scientific inquiry	General value of science	Personal value of science	Overall science performance
Support for scientific inquiry*	---	**0.568** *0.02*	**0.513** *0.01*	**0.413** *0.00*
General value of science	**0.546** *0.01*	---	**0.634** *0.01*	**0.335** *0.01*
Personal value of science	**0.472** *0.01*	**0.609** *0.01*	---	**0.340** *0.01*
Overall science performance	**0.355** *0.01*	**0.291** *0.02*	**0.213** *0.02*	---

*Scale based on items embedded in science test.
OECD average correlations in shaded boxes.
Significant correlations are shown in bold.

In Ireland, the correlation between *self-efficacy in science* and overall science is 0.45, while that between *self-concept* and overall science is 0.39 (Table 7.21). The association between variables such as self-efficacy and overall science is complex. For example, self-efficacy may increase as a result of doing well on a science test, while self-efficacy may also contribute to a strong performance in science. Of particular interest is the relatively strong correlation between *self-efficacy in science* and *self-concept in science* (0.54). This is perhaps not surprising since items underpinning the *self-efficacy in science* and *self-concept in science* indices both ask about students' self-perceptions of their science performance, albeit in somewhat different contexts.

Table 7.21: Correlations among indices of self-belief as science learners and correlations between indices and overall science performance

	Self-efficacy in Science	Self-concept in Science	Overall science performance
Self-efficacy in Science	---	**0.538** *0.01*	**0.446** *0.01*
Self-concept in Science	**0.446** *0.01*	---	**0.393** *0.02*
Overall science performance	**0.393** *0.02*	**0.277** *0.02*	---

OECD average correlations in shaded boxes.
Significant correlations are shown in bold.

In Ireland, the correlation between *interest in learning scientific topics* (which is based on items embedded in the science test) and overall science is weak-to-moderate (r = 0.14) (Table 7.22). This indicates that students who expressed greater interest in learning more about the topics around tasks they completed in the PISA assessment tend to do marginally better on overall science than students who expressed less interest. The corresponding average correlation across OECD countries is 0.09. The interdependence among scales is again evident in the correlations between *interest in learning science topics* and *general interest in science* (0.57 in Ireland, and 0.55, on average, across OECD countries). In Ireland, the strong correlation between *instrumental motivation to learn science* and *enjoyment of science* (0.62) suggests that those who perceive science to be valuable to them enjoy science (and vice versa).

Table 7.22: Correlations among indices/scales of interest in science and correlations between indices/scales and overall science achievement

	Int. in learning science topics	General interest in science	Enjoy. of science	Future-science motivation	Instrum. motivation	Engage in science-related activities	Overall science performance
Int in learning science topics*	---	**0.565** *0.01*	**0.519** *0.01*	**0.437** *0.01*	**0.399** *0.01*	**0.485** *0.01*	**0.135** *0.00*
General interest in science	**0.552** *0.01*	---	**0.696** *0.01*	**0.594** *0.01*	**0.557** *0.01*	**0.549** *0.01*	**0.337** *0.01*
Enjoyment of science	**0.501** *0.01*	**0.626** *0.01*	---	**0.686** *0.01*	**0.615** *0.01*	**0.603** *0.01*	**0.403** *0.01*
Future-science motivation	**0.375** *0.01*	**0.507** *0.01*	**0.597** *0.01*	---	**0.741** *0.01*	**0.528** *0.01*	**0.305** *0.02*
Instrumental motivation	**0.375** *0.02*	**0.484** *0.01*	**0.537** *0.01*	**0.646** *0.01*	---	**0.446** *0.01*	**0.281** *0.02*
Engagement in science	**0.445** *0.01*	**0.526** *0.01*	**0.588** *0.01*	**0.482** *0.01*	**0.408** *0.01*	---	**0.264** *0.02*
Overall science performance	**0.092** *0.01*	**0.259** *0.02*	**0.307** *0.02*	**0.204** *0.02*	**0.186** *0.02*	**0.194** *0.02*	---

*Scale based on items embedded in science test.
OECD country average correlations in shaded boxes.
Significant correlations are shown in bold.

Correlations between *awareness of environmental issues* and overall science achievement (0.43 in Ireland, 0.45 across OECD countries) are moderately strong, and indicate that students who are more aware of environmental issues perform better in science (Table 7.23). On the other hand, correlations between *concern for environmental issues* and overall science are weak (0.04 in Ireland, and 0.06 across OECD countries). This may suggest that students at all levels of ability are concerned about environmental issues. The negative correlations between *optimism regarding environmental issues* (−0.18 in Ireland, −0.11 across OECD countries) indicate that, in general, lower-achieving students are more optimistic than higher-achieving students that environmental problems will be resolved in the future.

Table 7.23: Correlations among indices of responsibility towards resources and the environment and correlations between indices and overall science

	Awareness of env. issues	Concern for environ. issues	Optimism regarding env. issues	Respons. for sustainable development	Overall science performance
Awareness of env. issues	---	**0.130** *0.02*	**−0.088** *0.02*	**0.368** *0.02*	**0.425** *0.01*
Concern for env. issues	**0.097** *0.02*	---	**−0.053** *0.02*	**0.265** *0.02*	**0.036** *0.02*
Optimism env. issues	**−0.113** *0.02*	**−0.099** *0.02*	---	**−0.119** *0.02*	**−0.175** *0.01*
Responsibility for sus. devel.	**0.273** *0.02*	**0.289** *0.02*	**−0.110** *0.02*	---	**0.319** *0.01*
Overall science performance	**0.451** *0.01*	**0.060** *0.02*	**−0.189** *0.02*	**0.269** *0.02*	---

OECD country average correlations in shaded boxes.
Significant correlations are shown in bold.

Science-Related Careers at Age 30

Students were asked to indicate what kind of job they expected to have at age 30. Responses were classified as defined in the International Standard Classification of Occupations (ISCO-88; International Labour Office, 1990). Science-related careers were defined as those involving a considerable amount of science, as well as those involving tertiary education in a scientific field. Hence, this is a broader definition than is found in other contexts. Inset 7.2 provides examples of the top 10 categories of science-related careers selected by Irish students. Careers listed include medical doctor, physiotherapist, psychologist, and computer systems analyst. Students were categorised according to whether they intended to pursue a science-related career or not. In Ireland, 29% of students indicated that they would pursue a science-related career, with roughly equivalent percentages of males (28) and females (30) intending to do so (Table 7.24). On average across OECD countries, one-quarter of students intended pursuing a science-related career – 24% of males and 27% of females.

In Ireland, students intending to pursue a science-related career at age 30 had a significantly higher mean score on overall science (545.6, SE = 3.58) than students not intending to (494.6, SE = 3.27). Similarly, on average across OECD countries, students intending to pursue a science-related career had a higher mean score on overall science (536.7, SE = 0.79) than students without this intention (489.2, SE = 0.54). Significant differences in overall science between students intending to pursue a science career and those not intending to do so were also found for male and female students (OECD, 2007c, Table 3.12). Examining only those who intended to pursue a science-related career, students in Ireland whose parent(s) had a science-related career obtained a mean science score that was 38 points higher than students who did not have at least one parent in such a career.

Table 7.24: Percentages of students, overall and by gender, in Ireland and on average across OECD countries, who intend to have science-related careers by age 30

	Ireland		OECD	
	%	SE	%	SE
All	29.3	0.85	25.2	0.15
Male	28.3	1.25	23.5	0.02
Female	30.2	0.92	27.0	0.19

Source: OECD (2007c), Tables 3.12 and 3.13.

Inset 7.2: Top 10 science-related career categories chosen by Irish students

Medical doctor

Physiotherapist / chiropractor / osteopath

Architect / town planner / engineer

Nurse / midwife

Veterinarian

Psychologist

Social work professional

Pharmacologist / pathologist

Computer systems designer / analyst

Biologist / botanist / zoologist

Summary

The assessment of students' engagement in, and attitudes towards, science was a significant component of PISA 2006. Some measures were embedded in the achievement test; others were in the student questionnaire.

Unfortunately, only three indices (all based on questionnaire items) – *awareness of environmental issues*, *general value of science,* and *self-efficacy in science* – were considered to be cross-nationally comparable. Student scores on these summary measures related in a consistent manner to overall science achievement, within and between countries. Among OECD countries, Ireland and Poland had the highest mean scores on *awareness of environmental issues*, though fewer students in Ireland (26%) than on average across OECD countries (35%) reported familiarity with issues around the use of genetically modified crops. Students in Ireland had mean scores that were close to the OECD average on the remaining scales – *general value of science* and *self-efficacy in science*. While large proportions of students in Ireland and across OECD countries agreed or strongly agreed with statements underlying the *general value of science* scale, just two-thirds of students in Ireland and three-quarters on average across OECD countries expressed these levels of agreement with the view that advances in science and technology usually bring social benefits.

Several indices can only be interpreted safely at national level because of inconsistent associations between the indices and achievement within and between countries. However, component items based on frequencies can be compared across countries. A consideration of the components of *general interest in science* shows more students in Ireland expressing high or medium interest in human biology and biology of plants than in chemistry or physics. Engagement by students in Ireland in activities such as watching TV programmes about science or reading science magazines or science articles in newspapers is low relative to the OECD average engagement levels, and perhaps points to something that can be encouraged to a greater extent. On the other hand, it is clear that students in Ireland have a strong *instrumental motivation to learn science*, with 68% reporting that studying school science subjects is worthwhile because what they learn will improve their career prospects (the corresponding OECD average is 62%).

On the two embedded measures of attitude, *interest in learning about science topics* and *support for scientific enquiry*, students in Ireland had mean scale scores that were below the corresponding OECD country averages. This may relate in part to the particular sets of topics about which students were questioned – such as acid rain, genetically modified crops, and research on the development of flu vaccines – and the extent to which these topics are represented in curricula in Ireland and elsewhere.

In general, within Ireland, scores on the attitude indices and scales related in a consistent and positive manner to overall science achievement, though the strength of the relationship varied from one measure to another. Not surprisingly, one of the strongest correlations (0.45) was that between *self-efficacy in science* and overall science achievement. A related variable, *self-concept in science*, correlated moderately strongly with overall science (0.39) and with *self-efficacy in science* (0.54). An index that correlated negatively with overall science in Ireland was *optimism regarding environmental issues* (−0.18), suggesting that lower-achieving students were more likely to believe that environmental problems would resolve themselves over time, compared with higher-achieving students.

Male and female students in Ireland varied in their scores across the attitude indices and scales. For example, male students had higher mean scores on *self-efficacy in science, self-confidence in science*, and *engagement in science-related activities* while females had higher mean scores on *general interest in science* and *instrumental motivation to learn science.* There was no significant difference between male and female students in Ireland on the *enjoyment of science* index.

PISA used a broad definition of the science-related careers that included careers in medicine, architecture and social work as well as more traditional science-related careers. About 24% of students in Ireland indicated that they intended to have a science-related career by age 30. This is about the same as the corresponding OECD average (25%). No significant gender differences were apparent in the proportions of male and female students in Ireland intending to pursue science-related careers.

Chapter 8
School and Classroom Characteristics

In this chapter, we describe some characteristics of the schools that participated in PISA in Ireland, and relate aspects of the school environment to performance on PISA. There are six main sections. The first section examines the proportions of variance in science achievement scores of students that lie within and between schools. The second examines characteristics of schools' enrolments, including school size, gender and socioeconomic composition. The third examines resources available in schools, and principals' views on their adequacy. In the fourth section, some characteristics of science teachers and science teaching practices are briefly described. The fifth section describes issues related to promotion and uptake of science in the school, while the sixth examines school philosophy.

Variation Between Schools

As well as comparing countries on achievement on PISA tests, we can compare differences between countries in the amount of variation that lies between schools (between-school variance) and the proportion that lies within schools (within-school variance).[1] Differences in proportions can be attributed to structural characteristics of education systems. For example, in a hypothetical country where students were randomly assigned to schools, we would expect very small differences between the mean scores of schools (low between-school variance), but considerable variation in the performance of each school's enrolment (high within-school variance)[2]. In countries where schools select entrants on the basis of academic performance, or where selection is linked to socioeconomic status, we would expect large differences between the mean scores of schools (high between-school variance), but little variation in the performance of each school's enrolment (low within-school variance).

As part of the analyses of the PISA 2006 data, the OECD examined the extent to which within- and between-school variance could be explained by student and school ESCS (the PISA measure of economic, social and cultural status) and study programmes. Consequently, the analyses did not include students who had missing data on any one of these variables. Here, we present additional analyses, based on the full sample of students who took part in PISA 2006. The latter has the advantage of providing more comprehensive coverage of the situation in participating countries, while the OECD analyses have the advantage of greater explanatory power. Readers should note that, due to the slightly different population coverage, the percentages of variance reported as attributable to within- and between-school factors are slightly different for each method of analysis.

[1] The proportion of variance that is between schools is also referred to as the intra-class correlation.

[2] This simplified explanation does not consider that differences between schools may arise from the policies and practices of schools and teachers, as well as from intake characteristics.

In Ireland, 17.2% of the variance in student science achievement is attributable to differences between schools (Table 8.1). This is approximately half the OECD average for between-school variance and the 8th lowest percentage amongst OECD countries. A contrasting example is The Netherlands, where almost 60% of the variation in student performance is between schools (meaning that Dutch schools tend to have a quite homogenous enrolment, with large differences between schools). Relatively speaking, Irish schools perform at a reasonably similar level to each other, with greater variation among individual students within a school. In this respect, Ireland is similar to countries such as New Zealand and Australia.

Table 8.1 Percentage of total variance in achievement in science, mathematics and reading that lies between schools – OECD countries

	Science	Mathematics	Reading
Finland	5.9	7.5	9.7
Iceland	9.4	9.3	12.6
Norway	10.5	11.2	12.6
Sweden	12.2	14.9	17.3
Poland	13.5	14.7	15.5
Spain	14.7	16.2	17.0
Denmark	15.9	17.4	19.5
New Zealand	16.7	16.1	18.8
Ireland	17.2	19.4	23.4
Australia	18.3	21.8	21.1
Canada	18.9	20.9	23.4
United Kingdom	19.9	22.9	22.4
United States	23.7	27.8	n/a
Luxembourg	29.6	32.1	28.7
Portugal	32.2	33.5	35.6
Korea	35.0	40.4	40.4
Switzerland	36.0	36.0	36.9
Mexico	40.0	42.3	41.0
Slovak Republic	42.5	48.8	49.6
Greece	46.7	41.6	48.6
Japan	47.4	53.3	50.1
Italy	50.5	52.3	51.8
Belgium	51.9	52.7	53.9
Czech Republic	52.9	54.7	56.0
Turkey	53.2	53.4	47.8
France	53.8	56.0	57.4
Austria	54.6	56.1	56.3
Germany	56.7	60.8	67.5
Netherlands	59.9	63.4	62.1
Hungary	61.2	65.2	68.0
OECD Average	32.7	34.7	36.0

Ireland is also part of a subset of countries in which consistency across schools was accompanied by a reasonably high level of performance. Finland is the exemplar of this category, with the smallest intra-class correlation in the OECD for science, mathematics and reading, coupled with a rank of first or second in each domain.

Finland's overall variance in student performance is also one of the smallest in OECD countries. This has been interpreted as indicating that it is possible to maintain minimum differences between students and schools while also achieving high average performance. Table 8.1 also shows data on between-school variance for reading and mathematics. In Ireland, between-school variance for reading is noticeably higher (23.4%) than for science (17.2%). This may, in part, be due to large gender differences in reading and the fact that one in four Irish schools is a single-sex school.

As noted, OECD analyses examined how much between- and within-school variance can be explained by ESCS and study programmes. In Ireland, these variables account for most (67.4%) of the variation between schools, but just 10.1% of the variation within schools (OECD, 2007c, Table 4.1a). The addition of study programme adds little explanatory value in Ireland, perhaps because almost all students experienced the same Junior Cycle programme for three years, thereby minimising current programme effects. Furthermore, the classification used groups Transition year and Leaving Certificate Applied students together (under vocational-oriented programmes), making interpretation difficult.

By comparison, at an OECD level, ESCS accounts for 62.2% of the variation between schools, but ESCS and study programme together account for 73.7%. Both also account for an OECD average of 9.0% of variation within schools. More extreme examples are Finland and The Netherlands. In Finland only 27.2% of between-school variance is explained by ESCS and study programmes, while in The Netherlands, the same variables explain 94.4% of the sizeable variance between schools. Thus, ESCS gives a relatively poor explanation of school-level achievement in Finland, a passable explanation in Ireland, and a good explanation in The Netherlands.

Enrolment Characteristics

This section summarises some features of the enrolment of schools that participated in PISA, including school size, sector, and socioeconomic and gender composition. Readers should be aware that while we examine a number of features of schools other than socioeconomic composition, it is difficult to disentangle the effects of socioeconomics from these other features; for example, school gender composition is closely linked with school sector, which is in turn closely linked with socioeconomic composition. Thus, an apparent 'advantage' for all-female schools might be more closely linked with differences in socioeconomic composition than with gender composition. Related to this, the final multi-level model of Irish science achievement in PISA 2003 included neither school size nor sector (despite initial analyses showing significant performance differences for these variables) as most of the variance was accounted for by school-level socioeconomic composition (Cosgrove et al., 2005).

Socioeconomic Composition

As noted in Chapter 6, each student was assigned a score on a PISA scale of Economic, Social and Cultural Status (ESCS). As well as linking individual ESCS to performance on PISA, it is possible to examine the effects of school-level ESCS on performance. For example, a student may have a relatively high score on ESCS, yet attend a school where the average ESCS is quite low. Overall, however, the relationship between school-level ESCS and achievement is very similar to that between student-level ESCS and achievement (Table 8.2). The highest mean score (539) was obtained by students in high ESCS schools (those in the top third of the distribution when school-level ESCS scores were assigned to individuals). The next highest mean score was obtained by students in medium ESCS schools (512), with the lowest mean obtained by students in low ESCS schools (475).

Table 8.2: Mean science scores of Irish students, by school-level ESCS

	Frequencies	Science	
	%Total	Mean	SE
Low	33.6	**474.5**	5.9
Medium	32.9	**511.6**	3.3
High (Reference group)	33.5	539.1	3.8
All Available	100.0	508.3	3.2

Significant differences in bold.

Most students in the low ESCS school category are themselves in the low ESCS category, meaning that their low achievement might be linked to their *personal* ESCS rather than to school-level ESCS. Table 8.3 attempts to separate the effects of personal and school ESCS by showing the relationship between school-level ESCS and achievement *for low ESCS students only*. Even if only low ESCS students are considered, there is a significant link between school-level ESCS and student performance. The highest mean score (497) was obtained by low ESCS students in high ESCS schools, followed by low ESCS students in medium ESCS schools (486), with the lowest mean obtained by low ESCS students in low ESCS schools (457).

Table 8.3: Mean science scores of low ESCS Irish students, by school-level ESCS

	Frequencies	Science	
	%Total	Mean	SE
Low (Reference group)	52.0	457.3	6.9
Medium	31.7	**486.0**	4.6
High	16.3	**496.8**	6.3
All Available	100.0	472.8	4.4

Significant differences in bold.

The one-quarter of students who were enrolled in schools designated as disadvantaged[3] obtained a mean of 480, significantly lower than the mean of 518 obtained by students attending non-designated schools (Table 8.4).

Table 8.4: Mean science scores of Irish students, by disadvantaged status

	Frequencies	Science	
	%Total	Mean	SE
Not disadvantaged (Reference group)	74.8	517.9	3.1
Disadvantaged	25.2	**479.8**	6.9
All Available	100.0	508.3	3.2

Significant differences in bold.

[3] Designated disadvantaged status (rather than the more recent DEIS system of classifying schools by level of disadvantage) is reported as, at the time of sampling, DEIS data were unavailable and schools were selected using disadvantaged status as an implicit stratification variable.

Another measure of the socioeconomic composition of a school is the proportion of students in the school that are entitled to a Junior Certificate fee waiver (broadly similar to the percentage of students covered by the medical card scheme, and an indicator of disadvantage in a school). There were moderate negative correlations between the percentage of a school's 2006 Junior Certificate candidates entitled to a fee waiver and performance on PISA domains, ranging from –.32 for reading literacy to –.29 for science (Table 8.5).

Table 8.5: Correlations between the percentage of Third year students in a school entitled to a Junior Certificate examination fee waiver and mean scores in all domains

	r	SE
Science	**–0.287**	0.03
Maths	**–0.308**	0.03
Reading	**–0.318**	0.04

Significant correlations are shown in bold.

School Sector

More than half (60%) of all students who participated in PISA attended secondary schools, with much smaller percentages attending vocational (24%) or community/comprehensive (17%) schools (Table 8.6). The mean science score of 521 obtained by secondary school students is significantly higher than the means obtained by students in either community/comprehensive (501) or vocational (481) schools.

Table 8.6: Mean scores of Irish students on the science scale, by school sector

	Frequencies	Science	
	%Total	Mean	SE
Comm./comp.	16.8	**501.3**	6.5
Secondary (Reference group)	59.6	521.3	3.7
Vocational	23.6	**480.7**	7.1
All Available	100.0	508.3	3.2

Significant differences in bold.

However, readers should be aware that there are very large differences in the socioeconomic composition of the three types of school. For example, the mean ESCS score of students attending vocational schools (–0.31) is well below both the Irish and OECD means, and indicates a relatively disadvantaged cohort. At –0.11, the ESCS mean for community/comprehensive schools is also below both Irish and OECD means, though not to as pronounced an extent. In contrast, the ESCS mean of 0.12 of students enrolled in secondary schools is above both Irish and OECD means, and indicates a relatively advantaged group of students.

School Size

As part of the initial PISA sampling process, schools were divided into three groups, based on the number of 15-year-olds enrolled. School size was defined as follows: small schools (less than 41 15-year-olds enrolled); medium (41 to 80); and large schools (81+). Over two-thirds of participating students were enrolled in large schools, one-quarter in medium-sized schools and only 6% in small schools[4] (Table 8.7). Students in large schools obtained a significantly higher mean science score than students in medium or small schools (by 30 points and 48 points, respectively). For reading and mathematics, a similar pattern of mean scores emerged. However, in those domains, the difference was significant only when large schools were compared with medium-sized schools.

Table 8.7: Mean scores of Irish students on the science scale, by school size

	Frequencies	Science	
	%Total	Mean	SE
Small	6.2	**471.3**	20.0
Medium	25.7	**488.9**	5.8
Large (Reference group)	68.1	519.0	3.5
All Available	100.0	508.3	3.2

Significant differences in bold.

Gender Composition

Over half (58%) of students were attending mixed-sex schools, and students in such schools obtained a mean science score of 498, which is significantly lower than the means obtained by students in either all-male or all-female schools (Table 8.8). The science mean scores were identical in all-male and all-female schools. On mathematics, students in mixed-sex schools were outperformed by students in all-male schools, but not by students in all-female schools. In contrast, for reading, students in mixed-sex schools were outperformed by students in all-female schools, but not by students in all-male schools.

Table 8.8: Mean scores of Irish students on the science scale, by school gender composition

	Frequencies	Science		Maths		Reading	
	%Total	Mean	SE	Mean	SE	Mean	SE
All-male	18.7	**522.0**	8.6	**521.7**	7.8	516.5	9.1
All-female	23.2	**522.0**	4.9	506.4	4.8	**550.1**	5.6
Mixed (Ref group)	58.1	498.4	4.2	493.0	3.6	504.4	4.1
All Available	100.0	508.3	3.2	501.5	2.8	517.3	3.5

Significant differences in bold.

[4] School size was linked to sector. For example, while 15.1% of students in the vocational school sector were enrolled in small schools, this was true of only 3.5% of secondary school students.

It is also possible to relate achievement on PISA to the proportion of a school's enrolment that is female. Doing so reveals that there is a non-significant correlation between percentage female enrolment and PISA science or mathematics achievement, and a weak-to-moderate association (.12) with reading (Table 8.9).

Table 8.9: Correlations (for Ireland) between the percentage of school enrolment that is female and performance on PISA domains

	r	SE
Science	0.004	0.03
Mathematics	–0.062	0.03
Reading	**0.125**	0.04

Significant differences in bold. The t-values for the non-significant correlations are 0.14 and −1.84, respectively.

School Resources

In Ireland, the student:computer ratio showed a weak-to-moderate negative correlation with achievement in all PISA domains, ranging from –0.14 for science to –0.17 for reading, meaning that students in schools with a poor student:computer ratio tended to outperform students in schools with a better ratio (Table 8.10). This (perhaps surprising) finding may be explained by the link between computer resources and school socioeconomic status. For example, in PISA 2006, schools designated as disadvantaged had a significantly better ratio of computers to students than non-designated schools. The average student:computer ratio[5] in Ireland was one computer to every ten students, compared to an OECD average of about one computer per 6 or 7 students (Table 8.11). Ireland's ratio is roughly half a standard deviation below the OECD average and ranks 22nd of 29 OECD countries[6] in terms of computer availability in schools.

Table 8.10 Correlations between school student:computer ratio and performance of Irish students, all domains

	r	SE
Science	**–0.143**	0.04
Mathematics	**–0.158**	0.05
Reading	**–0.170**	0.05

Significant differences in bold.

On an index of the perceived adequacy of material educational resources, Ireland's score of –0.32 was below the OECD average of 0.0 (Table 8.11). The index was derived from principals' views of the adequacy of resources such as computers and software, library materials, audio-visual resources, and science laboratory equipment. The Irish mean on the index indicates lower satisfaction with resources among Irish principals than among principals in OECD countries generally. However, while at an OECD level scores on the index were positively related to student

[5] The ratio includes only computers available for teaching and learning (class level unspecified).

[6] Data from France were excluded for this measure.

performance, in Ireland there was no significant relationship between principals' perceptions of the adequacy of resources and student performance on science.

Human Resources

PISA 2006 included some measures of human resources in schools. This was done by investigating school principals' opinions and also by computing a number of simple indices, such as the ratio of students to teachers. In Ireland, the student:teacher ratio was similar to the OECD average (roughly 13 students per teacher, excluding teaching staff in administrative positions, but including support teachers) (Table 8.11). Further, the percentage of teachers in Irish schools who were fully qualified was higher than the OECD average (97% versus 87%, respectively). Principals also provided information on vacancies for science teachers in the previous academic year. More than half (55%) of Irish students attended schools that had no such vacancies in the previous school year, compared to an average across OECD countries of 38%. Where there were vacancies, just 1% of Irish students were in schools where all available positions were not filled, while the average figure for the OECD was 5%.

Principals were asked whether teaching in their school was affected by a lack of qualified teachers. In the case of science, mathematics and English teachers, over 90% of students in Ireland were in schools where the principal felt a shortage of qualified teachers had little or no effect. However, over one-third of Irish students attended schools where a lack of qualified teachers of at least one 'other' subject was felt to interfere with teaching, either to 'some extent', or 'a lot'. On the resultant OECD index of teacher shortage, Ireland scored below the OECD mean of 0.0, indicating that teacher shortage is perceived to be less of a problem by Irish principals than by principals in most other OECD countries. On average across OECD countries, the index was negatively related to student achievement (meaning that teacher shortages were associated with poorer performance). In Ireland, however, the teacher shortage index was unrelated to achievement.

Table 8.11: Selected measures of school resources (Irish and OECD averages)

	IRL	OECD
Mean score on index of *quality of educational resources*	–0.32	0.0
Student: computer ratio	10.2:1	6.6:1
Student: teacher ratio	13.3:1	13.4:1
Percent of teachers fully qualified	97.4%	86.5%
Percent of third year science vacancies unfilled	1.1%	5.0%
Percent reporting instruction is 'not at all' / 'very little' hindered by lack of qualified *science* teachers	90.9%	83.0%
Percent reporting instruction is 'not at all' / 'very little' hindered by lack of qualified *mathematics* teachers	93.4%	84.1%
Percent reporting instruction is 'not at all' / 'very little' hindered by lack of qualified teachers of *PISA test language*	94.0%	88.1%
Mean score on index of *teacher shortage*	–0.21	0.0

Teacher and Classroom Characteristics

In Ireland, an additional questionnaire (not part of the international survey) was developed for teachers of Junior Certificate science. The results of the science teacher questionnaire were presented in an earlier publication – *Implementing the revised Junior*

Certificate Science Syllabus – What teachers said (Eivers et al., 2006) – and are therefore only briefly summarised here. Data from the teacher questionnaire cannot be directly linked to individual students, as we do not know which teachers taught which students. Thus, unlike most data presented in this report, we do not link data on teachers and classrooms to achievement. This section simply provides a general background against which student performance can be interpreted.

Teacher Background Characteristics

In total, 688 science teachers from 163 of the participating schools responded to the questionnaire, giving a response rate of 93.6%. Overall, 61.2% of teachers were female, with 38.8% male. Just 4.3% were in their first year of teaching, while the average number of years teaching was almost 17 years. Almost all (96.6%) had completed an undergraduate degree in which science was a major or a minor component. Respondents averaged just over 20 teaching hours per week, with 36.3% of this time spent teaching Junior Cycle science classes, 28.4% spent with Leaving Certificate science classes, and 4.0% spent teaching Transition Year science. Almost one-third of time was spent teaching non-science subjects (including mathematics and geography).

In terms of the syllabus being implemented with students sitting the Junior Certificate science examination in 2006, most teachers (72.7%) reported that they had implemented the rJCSS, while 19.5% reported that they did not have an examination class in 2006. Thus, 7.8% of teachers surveyed were implementing the old syllabus with their Junior Certificate examination class.

Teaching Practices

In terms of lesson planning for Third year students, the most frequently used resources were student textbooks (86.0% used textbooks to plan at least half of lessons), followed by the science syllabus (used by 60.7% of teachers to plan at least half of lessons). Similarly, the resource most commonly used in Third year classes was student textbooks – used in a majority of lessons by 79.8% of teachers. Most (59.0%) also used past or sample exam papers in over half of lessons, while 45.4% reported using workbooks and worksheets in over half of lessons. The percentage of teachers using workbooks in at least half of lessons was higher among those teaching the revised syllabus (45%) than among those teaching the old syllabus (30%).

Practical experiments were very common elements of Third year science lessons. Considering activities that occurred in at least half of lessons, 65.0% of teachers reported that students drew conclusions from an experiment, 56.0% reported that students did experiments by following instructions, while 24.4% reported that the teacher performed demonstration experiments. Only 5% of teachers of the rJCSS reported that their Third year students hardly ever or never did experiments by following instructions. When presented with a list of nine potential obstacles to effective teaching, 70.6% indicated that lack of technical support impeded their teaching of science to Third year students to a great extent. This was almost double the 36.4% who cited insufficient laboratory time (the next highest-rating obstacle) as an impediment.

Classroom Practice and the PISA Framework

One purpose of the science teacher survey was to examine links between the rJCSS, classroom practice, and PISA's conceptualisation of 'scientific literacy'. An important aim of PISA is to assess the extent to which students are prepared for future learning and for life after school. Consequently, teachers were asked to state, in their opinion, how well the rJCSS prepared students for a number of aspects of the world outside school, and to indicate how much emphasis they placed on developing particular skills (identified in the PISA science framework as important life skills) in their Third year science students. The skills for which the largest percentages of teachers reported placing 'a lot' of emphasis were: interpreting scientific evidence and drawing conclusions (40.4%), explaining conclusions reached and the scientific evidence on which they are based (40.2%), and applying scientific knowledge to a given situation (32.8%). In contrast, only 17.7% placed a lot of emphasis on distinguishing between scientific and non-scientific explanations and only 10.8% placed a lot of emphasis on distinguishing between questions that can be answered using a scientific approach and ones that cannot.

The lack of emphasis on distinguishing between scientific and non-scientific explanations may be related to teachers' views on how well the rJCSS prepared students for a number of aspects of the world outside school. While generally positive about the effects of the syllabus (e.g., almost all felt that it equipped students with the skills to understand scientific phenomena encountered in everyday life and to understand how science is used in the real world), 62.4% felt that the rJCSS did very little or nothing to help students critically read a newspaper or magazine article about a scientific experiment.

Promotion and Uptake of Science

In Ireland, extra questions were included in the school and student questionnaires regarding the status of science in the school. Three items (two of which were included in the school questionnaire and one in the student questionnaire) related to whether Junior Certificate science was compulsory in schools. Student responses were aggregated to the school level and (as responses were not always consistent within schools) compared to principals' responses. Schools were classified as providing either compulsory or optional Junior Certificate science if the responses from the principal matched the responses from a large majority of students in his or her school. All remaining schools were categorised as 'ambiguous'.

Overall, 25% of students fell into the 'ambiguous' school category, 63% attended schools where science was compulsory for Junior Certificate, and 12% attended schools where science was an optional subject. Students who attended schools with compulsory Junior Certificate science achieved a mean science score of 514.4, which is not significantly different from the mean of 506.7 achieved by students in optional science schools, but is significantly higher than the mean science score of 493.5 obtained by students in 'ambiguous' schools.

Schools Where Junior Certificate Science is Optional

In schools with optional Junior Certificate science, about one-half (53.2%) of students were in schools where students decide at the start of First year whether or not to take science. Roughly one-fifth (20.6%) were in schools where the decision to take science is made around the middle of First year, while 26.2% attended schools where students wait until near the end of their First year to choose. Access to 'taster' science courses was least common among students in schools where subjects were chosen at the start of First year (9.0% of such students attended schools that offered this). Taster courses were common in the very small number of schools where subjects were chosen around the middle of the year (74.0% of the subset of students in science-optional schools), and taster courses were available to all students in schools where the decision to take science was made at the end of First year. There was no significant difference in the mean science scores of students in schools that did and did not offer tasters[7].

In science-optional schools, principals provided information about which subjects competed with science when First year students made subject choices. The most common were home economics (95.9% of students in science-optional schools had to choose between this and science), art (86.3%), business studies (77.9%) and music (72.6%). Smaller proportions of students attended schools where foreign languages (37.1%) or a technological subject (34.7%) clashed with science.

Promoting Leaving Certificate Science

Irish principals were asked if their school had a formal policy to promote the uptake of science subjects at Leaving Certificate. Half (51.1%) of Irish students attended schools where such a policy existed. Of these students, most (88.9%) were in schools where the policy involved providing information to Third year and Transition year students about Leaving Certificate science subjects. Other popular approaches included allowing students to take biology, chemistry and physics for the Leaving Certificate (78.1% of students in a school with a formal policy) and encouraging all students to take at least one science subject (70.5%). Two-thirds (66.6%) of students attending schools with an uptake policy could take a Transition year module on Leaving Certificate science, while 42.8% could avail of a general science module in Transition year.

Principals in all participating PISA countries gave information about whether their school engaged in activities to promote the learning of science among Third year students. For example, 53.3% of Irish students attended schools that used extracurricular science projects to promote scientific learning among Third year students, while almost two-thirds (63.5%) were in schools that brought Third year students to science fairs (compared to OECD averages of 45.1% and 39.1%, respectively). Responses to these and other items were used to form an index of science promotion, with an OECD mean of zero and a standard deviation of one. Ireland's mean score on the index was 0.12, indicating a slightly above average level of activity to promote science. The index was divided into thirds for analysis, with students categorised as attending schools with either a low, medium, or high level of activity to promote scientific learning. Irish students in both low and medium promotion schools achieved a mean science score of 500, while students attending

---

[7] Readers should bear in mind that, where data for taster courses are discussed, the number of students is very small, as they represent a small subset of a subset of students.

schools with a high level of promotion of scientific learning achieved the highest mean science score (523), significantly outperforming the other two groups (Table 8.12).

Table 8.12: Mean science scores of Irish students, by level of school activities to promote the learning of science among Third years

	Frequencies		Science	
	%Total	%Available	Mean	SE
Low	39.1	39.8	**499.5**	5.6
Medium	23.8	24.2	**499.6**	6.2
High (Reference group)	35.3	36.0	523.2	4.5
Missing	1.8	0.0	524.0	24.6
All Available	98.2	100.0	508.0	3.2

Significant differences in bold.

When the component items are considered separately, only two of the activities were found to be related to Irish students' science achievement in PISA. Students who attended a school with science clubs for Third year students achieved a significantly higher mean score (522.0) than students in schools which did not offer this (504.1). School engagement in science competitions showed a similar link with achievement, with a mean score difference of 25 points on the science scale between the two groups. However, such activities were also related to school-level ESCS, meaning that schools with higher ESCS scores were most likely to have science clubs or to enter competitions.

School principals supplied information on school activities to encourage learning about environmental topics among Third year students. Questions included whether the school organised trips to museums or science technology centres, or invited guest speakers to talk to students about environmental topics. Ireland obtained a mean of 0.02 on the resultant index, which is very close to the OECD mean of 0.0. In contrast to the index of school science promotion, the environmental learning index showed no relationship with achievement, with students from schools categorised as low, medium, and high all averaging similar science scores (Table 8.13).

Table 8.13: Mean science scores of Irish students, by level of school activities for learning environmental topics

	Frequencies	Frequencies	Science	
	%Total	%Available	Mean	SE
Low	34.6	35.5	515.6	6.4
Medium	31.8	32.6	503.6	5.6
High (Reference group)	31.1	31.9	504.3	6.3
Missing	2.5	0.0	518.5	19.2
All Available	97.5	100.0	508.1	3.3

Significant differences in bold.

School Philosophy

In this section, we discuss some issues related to school philosophy and how such characteristics related to achievement. Issues of admission and inclusivity, streaming or grouping practices, and whether or not the school is considered to be public or private are discussed.

The main factors affecting school admittance in Ireland were residence in a particular area (42% of students attended a school where this was a prerequisite or high priority for admittance), having a family member currently or formerly attending the school (38%), and whether the student's parents endorse the ethos of the school, either educational or religious (27%) (Table 8.14). Smaller proportions of students attended schools where considerable weight was placed on recommendations from feeder schools (12%) or on whether the student wanted a specific programme or subject (14%). A very small minority of students (3%) attended schools that considered academic records to be a high priority in the selection process.

While a student's place of residence was a widely used admittance consideration across OECD countries (47% of students were enrolled in schools where it was a major factor), the need for familial connections or endorsement of school religious or educational ethos were far less common elements of admission policies in most OECD countries. In contrast, while academic record was a rare consideration in Ireland, it was a prerequisite or high priority factor in schools attended by 27% of students across OECD countries (and by over half of students in the OECD countries of Japan, The Netherlands, Austria, Hungary, Korea and Switzerland).

Table 8.14: Percentage of students in schools with certain admittance policies (Ireland and OECD)

Prerequisite or high priority	% IRL	% OECD
Residence in certain area	42.0	46.9
Attendance of family members	37.5	16.5
Parents endorse school philosophy (educational or religious)	27.3	11.9
Specific programme/subject	13.7	18.9
Recommendation from feeder school	11.8	12.6
Academic record	2.5	26.7

In Ireland, only 2% of students were in schools where the principals reported that Third year students were not ability grouped for any subjects. About nine out of ten Irish students attended schools with ability grouping for some Third year subjects, either within or between classes, while just 7.4% were in schools where grouping occurred for all subjects in Third year. Among OECD countries, only UK schools were more likely to place students in ability groups. In Ireland, the mean science score obtained by students in schools where no or some grouping took place was almost identical to the mean obtained by students who were ability grouped for all subjects (508.1 versus 508.5, respectively). Only one country (Qatar) of the 57 countries that took part in PISA 2006 showed a significant advantage for students in schools with ability grouping for all subjects compared to students in schools with grouping for some or no subjects (OECD, 2007c, Table 5.3). After accounting for ESCS, Qatar remained the only country to show an advantage for grouping, while in seven OECD and four partner countries, students in schools with no or limited ability grouping outperformed students in schools with ability grouping for all subjects (OECD, 2007c, Table 5.3).

As part of the analyses of the international dataset, the relationship between intake characteristics, selection, ability grouping and achievement was modeled (OECD, 2007b). This allowed examination of what are referred to as 'gross effects' (effects of schooling systems without reference to contextual factors) and 'net effects'

(effects after factors such as the ESCS composition of a school are considered). For example, while the gross effect of a selective intake system was an advantage of about 30 points on the science scale for students in such schools, the net effect (after accounting for variables such as socioeconomic status) was only 18 points. However, the apparent advantage from selectivity does not follow through from school level to national level. Thus, all things being equal, countries with a high percentage of selective schools do not perform better than countries with a low percentage. The model also indicated a net negative effect from ability grouping. It also showed that the earlier students are stratified into separate institutions or programmes, the stronger the effect of the school's average socioeconomic background on performance;[8] 'early selection into different institutional tracks appears to reinforce socio-economic inequalities in learning opportunities' (OECD, 2007b, p228).

A final element of school philosophy is whether the school is a public or private school. In Ireland, all vocational and community/comprehensive schools were classified as public, a large majority of secondary schools were classified as private government-dependent, and a small minority of secondary schools classified as private government-independent[9]. Thus, while on average 86% of students were in public schools in OECD countries, in Ireland only 42% were. However, although 58% of students in Ireland were in private schools, only 3% were in government-independent schools (OECD average, 4%).

On average across OECD countries, students in private schools (government-independent and -dependent) had a 25-point advantage on the science achievement test. The gap in Ireland was 34 points, larger than the OECD average, but considerably less than the 86-point gap in the UK (OECD, 2007c, Table 5.4). However, once differences in student and school intake characteristics were adjusted for, the advantage is reversed. Thus, once background characteristics are controlled, on average in OECD countries, students in public schools outperform students in private schools by roughly 12 points on the science scale. In Ireland, the public-private (or secondary-other) gap becomes non-significant. Of all OECD countries, a significant advantage for private school students was reported only for Canada, while a significant disadvantage was reported in seven (OECD, 2007c, Table 5.4).

Summary

In Ireland the percentage of variation in student science achievement that is attributable to differences between schools is about half the OECD average for between-school variance (17% versus 32%, respectively). Achievements in Irish schools were fairly similar; variation *within* schools was greater than the average in OECD countries.

---

[8] In Ireland, such stratification typically occurs at age 15, when students select Senior Cycle programmes. This is slightly later than the OECD average age of 14.

[9] Private schools (defined as controlled by a non-government organisation, or with a governing board not selected by a government agency) were divided into government-dependent or -independent based on the percentage of core funding received from government. Less than 50% was classified as government-independent, while more than 50% was government-dependent.

The enrolment characteristics of schools in Ireland were closely linked to student performance. Highest scoring schools included those not designated as disadvantaged, schools with a low percentage of students entitled to a Junior Certificate examination fee waiver, schools with large enrolments, and schools in the secondary sector. However, in most cases, these school characteristics were related to the socioeconomic composition of the school (as measured by ESCS). OECD analyses indicated that once ESCS (student- and school-level) were taken into account, the 'achievement advantage' found in Irish secondary schools was no longer significant.

Irish schools were more likely to use familial links and endorsement of a particular ethos as student admission criteria (and less likely to use academic record) than was the norm across OECD countries. With the exception of the UK, Ireland had the highest percentage of students (98%) attending schools where there was at least some ability grouping. In terms of resources, the Irish student:computer ratio of one to every ten students was considerably poorer than the OECD average of one to every six or seven students. However, the student:teacher ratio (which included support as well as classroom teachers) in Ireland was very close to the OECD average. Ireland also enjoyed a higher percentage of fully qualified teachers and a lower percentage of unfilled science teacher posts than the corresponding OECD averages.

A minority of schools did not have compulsory uptake of science for Junior Certificate. Students in these schools did not differ significantly on PISA science from students in schools where Junior Certificate science was compulsory. Half of Irish students attended schools with a formal policy to promote uptake of science subjects at Leaving Certificate. On an index of activities to promote the learning of science among Third year students, Ireland's mean score was slightly above the OECD average. Students attending schools with a high level of promotion of scientific learning had a significantly higher mean science score than students in schools with low levels of promotion.

Chapter 9
Summary and Implications

PISA is an international survey of 15-year-old students' *literacy* in science, mathematics and reading that takes place every three years. In PISA 2006, almost 400,000 students were assessed, spread across 57 countries, including Ireland and all 30 OECD member countries. In this chapter, we summarise the main findings of PISA 2006, before outlining some implications.

Summary of Main Findings

Findings are outlined, first by assessment domain, and then by factors related to achievement.

Science Performance

Science was the major assessment domain in 2006, and Ireland's performance was similar to Irish performance in 2000 and 2003 – slightly, but significantly above the OECD average on the overall science scale. The Irish mean score was 508, compared to the OECD average of 500. Ireland's mean score is the 14th highest of the 30 OECD countries, and the 20th highest of all participating countries. Applying a 95% confidence interval (see *Statistical Terms Used*), Ireland's true rank is between 10th and 16th among OECD countries. Unlike the average across OECD countries – where males significantly outperformed females – Irish males and females had almost identical scores on the overall science scale.

As similarities at the average level can hide quite different patterns of achievement between countries, we examined the gap between the scores of students at the 5th (i.e., very low achievers) and 95th (i.e., very high achievers) percentiles. This describes the range into which 90% of students' scores in a country fall, and is a more stable measure of the spread of achievement within a country than the highest and lowest scores. On the overall science scale, the difference of 309 points between Irish students at the 5th and 95th percentiles is very close to the OECD average of 311 points. In contrast, although Northern Irish students obtained an almost identical mean science score to Irish students, the gap between the two key markers was 366 points. Thus, in the Republic of Ireland, the range of science achievement is similar to the OECD average, while Northern Ireland has a much larger spread of achievement. Slightly more Irish students reached the baseline science proficiency level of 2 (where they 'begin to demonstrate the science competencies that will enable them to participate effectively and productively in life situations related to science and technology' (OECD, 2007b, p.44)) than was average across OECD countries (85% versus 81%, respectively).

As well as an overall scientific literacy score, scores are available for three science competencies. Irish students' best performance was on *identifying scientific issues*, achieving the 8th highest mean score among OECD countries. The Irish means for *using scientific evidence* and *explaining phenomena scientifically* were also above the corresponding OECD averages, but the difference is significant only for *using scientific evidence*. Irish students showed consistency in performance across the various *knowledge of* science subscales (*Earth and space systems*, *living systems* and *physical systems*) and did not fall below the OECD average in any of the subscales. Examining the details of science performance by gender, females in Ireland demonstrated particular strength in *identifying scientific issues* (mean score of 524 versus 508 for males), while males demonstrated particular strength in *Earth and space systems* (515 versus 501 for females) and *physical systems* (516 versus 493 for females).

The correlation between Junior Certificate science grade and performance on PISA science (r= .71) indicates that students who performed well on one tended to perform well on the other. PISA science items were rated on the expected familiarity of the underlying competency and concept to a Third year student of the revised Junior Certificate science syllabus (rJCSS). Most items were rated as either very familiar or somewhat familiar. This is in contrast to the last time PISA science items were rated (in PISA 2000), when the concepts underpinning roughly half of the items were rated as unfamiliar. Despite (or perhaps because of) the high expected familiarity levels with most items, there were only weak-to-moderate positive correlations between familiarity and the PISA science scores of students who had completed the rJCSS (.12 for concept familiarity and .13 for competency familiarity levels). A similar weak relationship (relative to reading and mathematics) between test familiarity and achievement on PISA science was found in analyses of the PISA 2000 data (Shiel et al., 2001).

Reading Performance

As in previous PISA cycles, the domain on which Irish students performed best was reading literacy. Ireland's performance has remained relatively stable over time, with Irish students consistently obtaining mean scores that are significantly above the OECD average. In 2006, Ireland's mean score on reading was 517, compared to the OECD mean of 492. In terms of country rankings, Ireland is the 5th highest of the 29 OECD countries[1] ('true rank': between 4th and 6th highest). Of all 56 countries for which reading data are available, only four (Korea, Finland, Hong Kong-China, and Canada) significantly outperformed Ireland.

The gap of 303 points between Irish students' scores at the key percentile markers (5th and 95th) for reading is much smaller than the OECD average of 324. Ireland also had proportionally fewer students falling below the baseline proficiency level of 2 than was average across OECD countries (12% versus 20%, respectively), and proportionally more students at the higher reading proficiency levels of 4 and 5. There are significant gender differences in performance on the reading assessment, in Ireland and in *all* countries that participated in PISA in 2006. In Ireland, females outperformed males by 34 points (534 versus 500), similar to the OECD average difference of 38 points. Only 8% of Irish females did not reach the baseline reading proficiency level, compared to 17% of Irish males.

[1] Reading literacy data for the United States were excluded due to an error in the test booklets, deemed to result in biased scores.

Mathematics Performance

Ireland's mean mathematics score in 2006 was 502, compared to an OECD average of 498. As in PISA 2000 and 2003, Ireland's mean was not significantly different from the OECD average. In terms of country rankings in PISA 2006, Ireland's mean score is the 16th highest of the 30 OECD countries ('true rank': between 12th and 17th highest) and the 22nd highest of all 57 participating countries.

Among OECD countries, Ireland and Finland have the narrowest spread of achievement for mathematics between scores at the 5th and 95th percentiles. 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. Unlike the situation in the case of reading and science, Ireland had proportionally fewer students at the highest proficiency levels in mathematics than the OECD average (approximately 10% of students versus an OECD average of 13%). On a more positive note, a smaller percentage of students in Ireland fell below the baseline proficiency level of 2 for mathematics (16%, versus an OECD average of 21%). As in most countries, males in Ireland outperformed females (507 versus 496, respectively), and the magnitude of the gap was very similar to the 11-point gap across all OECD countries. Less than 1% of females in Ireland, compared to 2.4% of males, achieved the highest mathematics proficiency level of 6.

Factors Related to Achievement

A number of student- and school-level factors were found to be significantly related to achievement. In particular, student socioeconomic status, as defined by the PISA measure of ESCS (economic, social and cultural status), was associated with achievement on each of the PISA domains of science, reading and mathematics. 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, mainly due to lower than average levels of cultural and educational resources in Irish homes. Nonetheless, ESCS was linked to achievement at the level of the individual student and (when aggregated) at the level of the school. Furthermore, factors such as school sector, size, and gender composition – all of which are linked to ESCS – were also related to achievement. However, analyses suggested that the underlying factor was ESCS rather than (for example) school sector or size.

As noted in the preceding sections, gender was related to achievement. There were no gender differences in overall science performance in Ireland (across the OECD, males outperformed females by a small margin). For mathematics, males outperformed females (in Ireland and most OECD countries) while females outperformed males on reading (in all participating countries). There was no significant difference in the mean scores obtained by 'native' Irish students and the 6% in Ireland not classified as native. Higher achievement was associated with smaller family size, higher parental educational attainment, and speaking either English or Gaeilge at home, rather than 'other' languages.

Many elements of the home environment – including number of books in the home, availability of educational resources, and the extent of student-parent interaction – were related to achievement. Comparing student background characteristics across the three PISA cycles revealed that while change was apparent in some characteristics (e.g., parental educational attainment had increased while family size had decreased), other elements of the home environment remained unchanged (e.g. number of books in the home, percentages of students with a study desk). In Ireland, major increases had occurred since PISA 2000 on the so-called 'affluence indicators', such as dishwashers, DVD players, TVs and mobile phones. Consequently, in 2006, Ireland was above the OECD average on most affluence indicators, but slightly below average on indices of educational resources and cultural possessions in the home.

In Ireland, the typical PISA student was in Third year (59%). Although mean scores tended to increase as grade level increased, highest scores in Ireland were obtained by Transition year students (but this could be attributable to their atypical socioeconomic composition). The slightly more than half of students who had not been absent from school in the two weeks preceding the assessment obtained higher mean scores than students who reported absences. A large group (43%) of students reported being bullied (e.g., name-calling or physical abuse) in the school term in which PISA took place. Those who had not experienced bullying in any form obtained higher mean scores than those who had. As was found in previous PISA studies, students who had not taken Junior Certificate science did not differ significantly in average science achievement score from students who had taken the subject at Ordinary Level.

Examining the variation in student science performance that can be attributed to differences *between* schools, the percentage in Ireland is about half the OECD average (17% versus 32%, respectively). This means that compared to the average across OECD countries, Irish schools performed at a reasonably similar level to each other, with greater variation found *within* schools. Compared to the norm for OECD countries, Irish schools were more likely to use familial links and endorsement of particular ethos as student admission criteria, and more likely to place students in ability groups. The student:computer ratio was considerably poorer in Ireland than the OECD average , but the student:teacher ratio (which included support as well as classroom teachers) was very close to the OECD average.

Attitudes to Science

Students in Ireland achieved a mean score that was well above the OECD average on one of the internationally comparable indices of attitude – *awareness of environmental issues*. On two other internationally comparable scales – *general value of science* and *self-efficacy in science* – students in Ireland achieved scores that were not significantly different from the corresponding OECD average scores. Fewer students in Ireland than on average across OECD countries indicated a 'high' or 'medium' interest in studying topics in chemistry or physics, but more indicated similar levels of interest in studying human biology and biology of plants. Students in Ireland reported very low levels of engagement in out-of-school science-related activities such as watching television programmes about science, reading science magazines or science articles in papers, or visiting websites about science topics.

Male students in Ireland and across OECD countries reported higher *awareness of environmental issues*, *self-efficacy in science* and *general value of science* than did females. On the nationally-comparable indices, females reported stronger *instrumental motivation to learn science*, and stronger *future-orientated motivation to learn science* than males. Many of the attitudinal scales correlated strongly with overall science achievement. In Ireland, an increase of one standard deviation in *self-efficacy in science* was associated with a 40-point increase in overall science, while a similar increase in *responsibility for sustainable development* was associated with a 33-point increase in overall science. On the other hand, an increase in *optimism regarding environmental issues* was associated with a drop in achievement, suggesting that lower-achieving students may be overly optimistic about the extent to which key environmental problems will resolve themselves over time. Most attitudinal scales that correlated significantly with achievement also correlated significantly with one another, and with socioeconomic status.

Implications of PISA 2006 Results

In this section we place the results of PISA 2006 in context. Some of the implications are domain-specific (e.g., changes to the mathematics syllabus) while others reflect more general systemic concerns.

Overall Performance in Science

Although the mean score of students in Ireland on overall science has been significantly above the OECD average in all three cycles to date, it must be acknowledged that, in the last two cycles in particular, Ireland has been just above the OECD average. Moreover, the use of a new, more lenient method by the OECD in 2006 to evaluate the significance of the difference between a country's mean score and the OECD country average means that additional care should be exercised in interpreting the status of countries such as Ireland that are on the borderline between significance and non-significance.

The finding that Ireland's performance on science has not improved since 2000 may be a matter of concern. In theory, the introduction of the revised Junior Certificate science syllabus (rJCSS) has created a closer alignment between PISA science and science as experienced by Irish students. For example, aspects of the PISA science framework are embedded in the rJCSS. There has also been a large increase in the percentage of PISA science items on topics expected to be familiar to Junior Certificate science students. Only 4% of science items were considered to be based on concepts that were unfamiliar to students, compared to close to half of the science items administered as part of the 2000 assessment (Shiel et al., 2001). It is thus a little surprising that there was no improvement apparent in student performance on PISA science in Ireland.

The rJCSS may not be in place long enough for it to have affected performance in PISA (2006 was the first year it was examined, and close to half of the students who took part in PISA had not studied the rJCSS). Thus, it is important to monitor the implementation of the syllabus over the next several years. In particular, it would be interesting to examine how two elements – the Science-Technology-Society (STS) approach and Coursework – are implemented in practice.

It may be that the STS approach espoused by the rJCSS is not fully reflected in teaching practices. Are students given opportunities to apply what they have learned in science classes, particularly with respect to the types of real-life contexts that students encounter in PISA? Also, it is unclear from a review of the first year of syllabus implementation if the mandatory experiments (Coursework A) and investigations (Coursework B) on the science syllabus promote or militate against the development of the types of scientific thinking promoted by PISA (see Eivers et al., 2006). Further, whether students' understanding of science is better supported through undertaking Coursework of their own design or by selecting from the set Coursework items is not yet established.

In terms of implementing the rJCSS as intended, the issue of laboratory technicians needs to be considered. Provision of technical support was advocated by the Task Force on the Physical Sciences (2002), while the absence of such support was rated by almost three-quarters of teachers surveyed by Eivers et al. (2006) as an impediment to teaching Third year science classes. It would be worth examining what effects the provision of technical support would have on students' experiences of Coursework. If teachers could spend less time setting up equipment, would it lead them to focus on developing and extending students' thinking and reasoning skills?

Ordinary Level Science and PISA Science

One might argue that Ireland's overall performance in science would improve if all students were required to take science as a subject at Junior Certificate level – something also advocated by the Task Force on the Physical Sciences (2002). As in PISA 2000 and 2003, students taking Ordinary Level science at Junior Certificate level did not perform any better on PISA science than students not taking Junior Certificate science. Moreover, those not taking science have similar levels of achievement in reading and mathematics to those studying science. This indicates that the lack of a gap in achievement is not due to, for example, generally higher academic ability among non-science students. While it cannot be claimed that students taking Ordinary Level science do not learn any science, it would appear that there is limited transfer between what they learn in science classes at school and performance on PISA science. This is surprising given that the comparison of the PISA science framework and the rJCSS (reported in Chapter 5) indicated a high degree of overlap, certainly relative to 2000, when the last test-curriculum comparison took place.

The finding of no difference in achievement between Ordinary Level students and non-science students suggests a need to examine in greater detail the characteristics of these students, not only in relation to their performance on specific aspects of PISA science (i.e., a detailed description of their knowledge and competencies), but also in terms of their attitudes towards and engagement in science.

Attitudes to and Engagement in Science

Almost all attitudinal scales correlated positively and significantly with achievement, including *self-efficacy in science* and *instrumental motivation to learn science*. However, the interpretation of these correlations is complex. For example, high levels of *self-efficacy in science* may lead to improvement in science achievement, or high levels of achievement may increase *self-efficacy*. Furthermore, *self-efficacy* is strongly associated with scales such as *self-concept in science* and with ESCS, making interpretation of associations with achievement quite complex. This suggests that caution should be exercised in interpreting associations between attitudinal indices and achievement, and underlines a need for additional research to disentangle associations between attitudinal variables and achievement.

The low engagement of students in Ireland in science-related activities such as watching a TV programme about science or reading a magazine or newspaper article is a cause of concern. Given the importance of applying scientific concepts to real-life situations (a cornerstone of the PISA assessment), there may be value in examining ways in which schools and parents can support students to engage more in science-related activities.

The negative association between *optimism regarding environmental issues* and science achievement indicates that students at the lower end of the achievement spectrum are relatively optimistic about environmental issues. Instilling pessimism in students is not to be recommended. However, it is important that students with limited scientific literacy should understand the challenges facing the environment and, perhaps more importantly, understand the role their own behaviour can play in shaping the environment.

Low- and High-Achieving Students

A characteristic feature of the performance of Irish students across all three cycles of PISA has been better-than-average achievement by lower-achieving students. For example, Ireland has relatively fewer students falling below the baseline proficiency level on the assessments of scientific, reading and mathematical literacy. The spread of achievement (the gap between those at the 5th and 95th percentiles) in Ireland also tends to be slightly narrower than the OECD average, and considerably narrower than in some other education systems (e.g., Northern Ireland), suggesting a more equitable distribution of achievement.

However, it is also the case that many other countries have a larger cohort of very high achievers. This is particularly true in mathematics, where the mean score of Irish students at the 95th percentile (very high achievers) was 30 points below the equivalent German score, even though Ireland and Germany obtained similar overall means. Even in reading – where Ireland's mean was well above the OECD mean – the mean score of Irish students at the 95th percentile was not markedly high. For example, it was within two points of the Polish mean at that marker, despite a 10-point difference in overall means between the two countries.

The PISA data suggest that while Ireland has had a measure of success in dealing with the needs of lower achievers, we have been less successful in meeting the needs of the higher-achieving student, particularly where mathematics is concerned. It is possible that our relative lack of high-achieving mathematics students is related to uptake of Junior Certificate mathematics (mathematics is one of only two Junior Certificate subjects for which a minority of candidates opt for the Higher level syllabus). Of course, other factors may warrant exploration. For example, Close and Oldham (2005) have contrasted the PISA focus on real-life mathematics with the emphasis on decontextualised examples typical in Irish post-primary schools. The content comparison of PISA 2003 mathematics and Junior Certificate mathematics conducted by Cosgrove et al. (2005) also revealed a dearth of coverage of three Junior Certificate mathematics topics (sets, geometry, and trigonometry). Thus, it could be argued that PISA is not assessing aspects of mathematics that are familiar to Irish students, and to which they may have devoted considerable time, leading to slightly depressed estimates of achievement. However, since PISA – unlike earlier studies such as TIMSS (Schmidt, McKnight, Valverde, Houang & Wiley, 1997) – did not include an analysis of participating countries' curricula, it is not possible based on available data to indicate the extent to which other countries were similarly affected. In any case, the performance of Irish students on the elements of mathematical literacy that *were* assessed remains somewhat disappointing.

The previous Irish report on PISA 2003 commented that it might be some time before the revised mathematics syllabus – introduced in 2000 and first examined in 2003 –influenced achievement (Cosgrove et al., 2005). Some time has elapsed, but no effect is (yet) apparent in the PISA scores. Further analysis would be needed to identify any underlying positive or negative trends over the period. It is to be hoped that new developments, such as Project Maths, may be diverse enough in content and focus to raise the achievement of high performers in mathematics as well as catering to the needs of students at other performance levels. As the relative lack of high-achieving students is most pronounced in mathematics, we have concentrated on the mathematics syllabus in this section. However, those involved in the teaching of English and science might also reflect on measures to stimulate higher achievement among more academically able students.

The Effects of the Home

The OECD produces a number of indices to summarise aspects of home life and how they relate to achievement. For some of these – e.g., parental education, educational resources and cultural possessions in the home – the relationship with achievement is clear and unambiguous. The higher parental educational attainment, the more books in a student's home, or the greater the availability of resources such as calculators or study desks, the better a student tends to perform on PISA. For affluence indices (e.g., the number of dishwashers, TVs or mobile phones), the relationship is less clear. In particular, more TVs or a premium cable TV package in the home is associated with poorer, not better, test performance.

Irish students were above the OECD average on almost all affluence indicators. In contrast, Ireland ranked 21st of the 30 OECD countries on the index of availability of educational resources in the home and 26th on an index of cultural possessions in the home. Since PISA 2000, Irish homes have shown very large increases in most affluence indicators (e.g., the number of TVs, mobile phones, dishwashers, computers, cars). In contrast, despite a very clear relationship with achievement, there has been no real shift in educational or cultural resources in the typical Irish home. For example, while approximately 11% more Irish students had their own room in 2006 than in 2000, the percentage with a study desk remains unchanged since 2000. This suggests either that parents are unaware of the findings from studies such as PISA, or that what knowledge they have does not influence their behaviour.

School Effects

The results from PISA 2006 show that, as in previous PISA cycles, there is less variance in performance between Irish schools than across OECD countries. Relatively speaking, Irish schools perform at a reasonably similar level to each other, with greater variation among students *within* a school. The results also indicate clear differences between the average performance levels of students attending different types of school. For example, we report higher mean scores for students attending schools that are single-sex, larger than average, in the secondary sector, or not designated as disadvantaged. However, the factor that appears to underlie all these differences is student socioeconomic status. Once the socioeconomic composition of a school's enrolment is taken into consideration, mean score differences tend to disappear. This suggests that the advantage to attending certain types of schools often derives from the characteristics that students bring to the school, rather than to 'added-value' from attending a particular school.

Gender Differences

The gender difference on overall PISA science in Ireland was not statistically significant, masking stronger performance by females on some aspects of science (e.g., *identifying scientific issues*), and stronger performance by males on others (e.g., *Earth and space systems* and *physical systems*). There may be some value in considering these differences (as well as the stronger *self-efficacy in science* among males and *instrumental motivation to learn science* among females) when implementing science teaching programmes.

The large difference in favour of females in PISA reading literacy (in Ireland and elsewhere) is a matter of concern, as is the related issue of poor performance by lower-achieving boys, while the relatively smaller difference in favour of males in PISA mathematics contrasts with the stronger performance of females on the Junior Certificate mathematics examination. Some researchers (e.g., Rowan, Knobel, Bigum & Lankshear, 2002; Weaver-Hightower, 2003) have proposed improving performance in reading literacy (for both males and females) by developing less stereotypical identities, in the context of using a broader range of traditional and non-traditional literacies (e.g., electronic media) in schools. One wonders if such efforts might lead to more balanced profiles of performance between males and females in mathematics and science as well as in reading literacy.

Changing Performance at a National Level

There has been little substantive difference in how Irish students have performed in PISA studies (2000 – 2006). This should not give the impression that change cannot be effected at a national level. For example, Korea and Poland have shown large improvements on the assessment of reading literacy (increases of 31 and 29 points, respectively, since 2000) (OECD, 2007b). Korea's improvement was achieved by very large changes in performance standards among higher performing students. In contrast, much of Poland's improvement between 2000 and 2003 occurred at the lower end of the performance distribution, but improvements across all levels of achievement have also taken place since PISA 2000. Not all changes were positive. Greek performance on reading dropped by 14 points between 2000 and 2006, largely due to poorer performance among lower achieving students.

Other countries have made significant gains (or, in some cases, losses) in mathematics. For example, Greek performance on mathematics between 2003 and 2006 improved by 14 points, while France, Northern Ireland, and the US recorded significant drops in mean mathematics scores since 2003. These examples illustrate that it is possible for change to occur in performance at a national level, although not always in the desired direction, and not always for obvious reasons.

Concluding Comments

Ireland will participate in the next cycle of PISA, when reading will once again be the major assessment domain. This will provide opportunity for the first detailed analyses of trend data as it represents the first time a major domain (reading) is repeated. We will also have the opportunity to monitor, over a longer period of time, the impact of the revised Junior Certificate science syllabus and, to a lesser extent given its timing, the effect of the developments in post-primary mathematics education which are due to get under way in September 2008.

References

Beaton, A.E., Martin, M.O., Mullis, I.V., Gonzalez, E.J., Smith, T.A., & Kelly, D.L. (1996). *Science achievement in the middle-school years: IEA's Third International Mathematics and Science Study*. Chestnut Hill, MA: TIMSS International Study Center, Boston College.

Carey, M. (1990). *Gender differences in attitudes and achievement in mathematics: A study of first year students in Irish post-primary schools.* Unpublished M.Ed thesis. Ireland: University of Dublin (Trinity College).

Carroll, J. (1963). A model for school learning. *Teacher College Record, 64*, 723-733.

Close, S., & Oldham, E. (2005). Junior Cycle mathematics examinations and the PISA mathematics framework. In S. Close, T. Dooley, & D. Corcoran (Eds.), *Proceedings of the First National Conference on Research in Mathematics Education* (pp. 174-192). Dublin: St Patrick's College.

Cosgrove, J., Shiel, G., Sofroniou, N., Zastrutzki, S., & Shortt, F. (2005). *Education for life: The achievements of 15-year-olds in Ireland in the second cycle of PISA*. Dublin: Educational Research Centre.

Creemers, B.P.M. (1994). *The effective classroom*. London: Cassell.

DES (Department of Education and Science). (2003). *Junior Certificate science syllabus (Ordinary level and Higher level)*. Dublin: Stationery Office.

Eivers, E., Shiel, G., & Cheevers, C. (2006). *Implementing the revised Junior Certificate Science Syllabus: What teachers said*. Dublin: Stationery Office.

Freudenthal, H. (1973). *Mathematics as an educational task*. Dordrecht: Kluwer Academic.

Ganzeboom, H.B., de Graaf, P., & Treiman, D.J. (with De Leeuw, J.) (1992). A standard international socioeconomic index of occupational status. *Social Science Research*, *21,* 1-56.

Gill, B., Dunn, M., & Goddard, E. (2002). *Student achievement in Northern Ireland: Results in reading, mathematical and scientific literacy among 15 year olds from OECD PISA 2000 study*. London: Her Majesty's Stationery Office.

International Labour Office. (1990). *International standard classification of occupations (ISCO-88)*. Geneva: Author

Kellaghan, T., & Dwan, B. (1995). *The 1994 Junior Certificate Examination: A review of results*. Dublin: National Council for Curriculum and Assessment.

Lapointe, A. E., Askew, J.M., & Mead, N.A. (1992). *Learning science.* Princeton, NJ: Educational Testing Service.

Macaskill, G., Adams, R.J., & Wu, M.L. (1998). Scaling methodology and procedures for the mathematics and science literacy, advanced mathematics and physics scales. In M. Martin & D.L. Kelly (Eds.), *Third International Mathematics and Science Study technical report. Volume 3: Implementation and analysis*. Chestnut Hill, MA: International Study Center, Boston College.

Martin, M.O., & Hickey, B.L. (1993). *The 1992 Junior Certificate Examination: A review of results*. Dublin: National Council for Curriculum and Assessment.

Martin, M.O., Hickey, B.L., & Murchan, D.P. (1992). The Second International Assessment of Educational Progress: Mathematics and science findings in Ireland. *Irish Journal of Education*, *26*, 3-146.

NCCA. (2006). *Junior Certificate science draft guidelines for teachers.* Retrieved October 13th, 2007 from http://www.ncca.ie/uploadedfiles/publications/JCScienceTGlines%203.1.pdf

OECD (Organisation for Economic Co-operation and Development). (1993). *Education at a glance: OECD indicators*. Paris: Author.

OECD. (1997). *Education at a glance: OECD indicators*. Paris: Author.

OECD. (2001). *Knowledge and skills for life: First results of PISA 2000.* Paris: Author.

OECD. (2004a). *Context framework 2006* (Document prepared by the PISA Consortium for the PISA Board of Participating Countries). Paris: Author.

OECD. (2004b). *Learning for tomorrow's world: First results from PISA 2003*. Paris: Author.

OECD. (2006). *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006*. Paris: Author.

OECD. (2007a). *Draft technical note on comparisons over time on the PISA scales.* (Document prepared by the PISA Consortium for the PISA Board of Participating Countries). Paris: Author.

OECD. (2007b). *PISA 2006: Science competencies for tomorrow's world, Volume 1: Analysis*. Paris: Author.

OECD. (2007c). *PISA 2006: Science competencies for tomorrow's world, Volume 2: Data*. Paris: Author.

OECD. (in press). *PISA 2006 technical report*. Paris: Author.

OECD/UNESCO-UIS (United Nations Educational, Scientific and Cultural Organisation Institute for Statistics). (2003). *Literacy skills for the world of tomorrow: Further results from PISA 2000*. Paris / Montreal: OECD / UNESCO-UIS.

Oldham, E. (1989). Is there an international mathematics curriculum? In B. Greer & G. Mulhern (Eds.), *New directions in mathematics education* (pp.185-224). London: Routledge.

Olweus, D. (1993). *Bullying at School: What We Know and What We Can Do*. Oxford, UK: Blackwell.

Rowan, L., Knobel, M., Bigum, C., & Lankshear, C. (2002). *Boys, literacy and schooling: the dangerous territories of gender-based literacy reform.* Buckingham: Open University Press.

Schmidt, W.H., & Cogan, L.S. (1996). Development of the TIMSS context questionnaires. In M.O. Martin & D.L. Kelly (Eds.), *Third International Mathematics and Science Study (TIMSS) Technical Report, Volume 1: Design and Development*. Chestnut Hill, MA: International Study Center, Boston College.

Schmidt, W.H., McKnight, C.C., Valverde, G.A., Houang, R.T. & Wiley, D. E. (1997). *Many visions, many aims. Volume 1: A cross-national investigation of curricular intentions in school mathematics*. Dordrecht: Kluwer.

Shiel, G., Cosgrove, J., Sofroniou, N., & Kelly, A. (2001). *Ready for life? The literacy achievements of Irish 15-year olds with comparative international data*. Dublin: Educational Research Centre.

Shiel, G., Perkins, R., Close, S., & Oldham, E. (2007). *PISA mathematics: A teacher's guide*. Dublin: Stationery Office.

Task Force on the Physical Sciences. (2002). *Report and recommendations.* Retrieved July 13, 2006 from *http://www.education.ie/servlet/blobservlet/physical_sciences_report.pdf*

Travers, K.J. & Westbury, I. (Eds.). (1989). *The IEA Study of Mathematics I: Analysis of mathematics curricula*. Oxford: Pergamon.

Weaver-Hightower, M. (2003). The 'boy-turn' in research on gender education. *Review of Educational Research, 73(4)*, 471-498.

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. Nine items from three units[1] 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**
Acid Rain	S485Q02	Open response	Social	Explaining phenomena scientifically	Physical systems
Acid Rain	S485Q02	Multiple choice	Personal	Using scientific evidence	Physical systems
Acid Rain	S485Q02	Open response	Personal	Identifying scientific issues	Scientific enquiry
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

[1] 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.

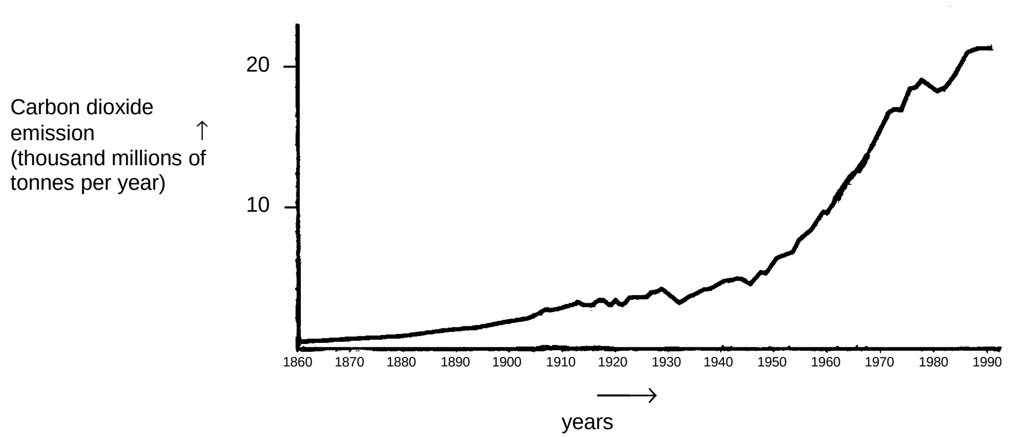
THE GREENHOUSE EFFECT: FACT OR FICTION?

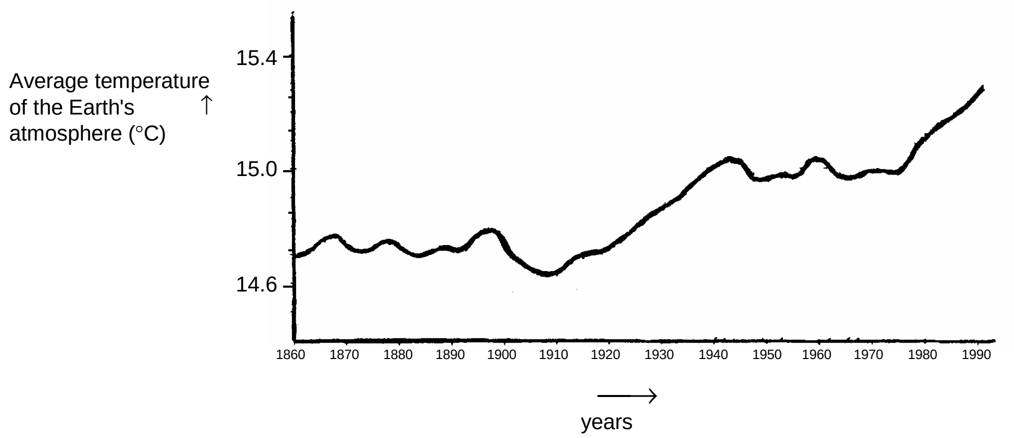
Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth. The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing 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		Item Difficulty
		IRL	OECD	
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.

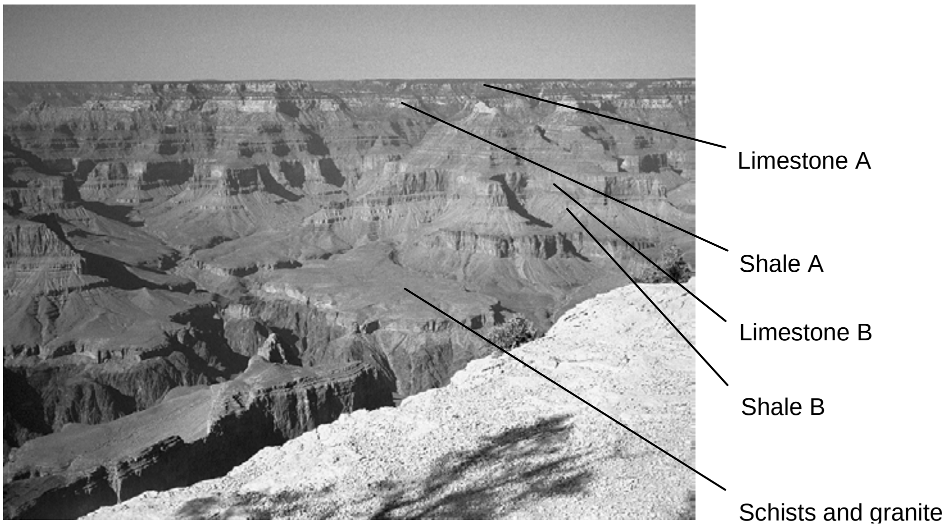
Score	Response required	% Correct		Item Difficulty
		IRL	OECD	
Full	Refers to one particular part of the graphs in which the curves are not both descending or both climbing and gives the corresponding explanation	23.0	22.4	Scale score 659 Level 5
Partial	Mentions a correct period, without any explanation ***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		Item Difficulty
		IRL	OECD	
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 IRL	% of responses OECD	Item Difficulty
Correct - Yes, No	**74.1**	**61.3**	Scale score 485 Level 3
Incorrect	25.2	37.3	
Missing	0.7	1.4	

Question 3: THE GRAND CANYON

The temperature in the Grand Canyon ranges from below 0 ^oC to over 40 ^oC. 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		Item Difficulty
	IRL	OECD	
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		Item Difficulty
	IRL	OECD	
Correct – C	**70.2**	**75.8**	Scale score 411 Level 2
Incorrect	26.4	20.6	
Missing	3.5	3.6	

ACID RAIN

Below is a photo of statues called Caryatids that were built on the Acropolis in Athens more than 2500 years ago. The statues are made of a type of rock called marble. Marble is composed of calcium carbonate. In 1980, the original statues were transferred inside the museum of the Acropolis and were replaced by replicas. The original statues were being eaten away by acid rain.

Question 2: ACID RAIN

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

Score	Response required	% of responses		Item Difficulty
		IRL	OECD	
Full credit	Gives any one of car exhausts, factory emissions, burning fossil fuels, or similar ***OR*** just refers to “pollution” (may also include a source of pollution that is not a significant cause of acid rain)	69.6	57.7	Scale score 506 Level 3
Incorrect		21.2	26.2	
Missing		9.2	16.1	

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

Question 3: ACID RAIN

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

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

Score	% of responses		Item Difficulty
	IRL	OECD	
Correct – A	**68.4**	**66.7**	Scale score 460 Level 2
Incorrect	29.7	31.1	
Missing	1.9	2.2	

Question 5: ACID RAIN

Students who did this experiment also placed marble chips in pure (distilled) water overnight. Explain why the students include this step in their experiment.

Score	Response required	% of responses		Item Difficulty
		IRL	OECD	
Full credit	Explains that the students used water to show that acid (vinegar) is necessary for the reaction	23.0	14.0	Scale score 717 Level 6
Partial credit	Refers to a comparison with the vinegar and marble test, without clarifying that vinegar is necessary for the reaction	45.4	43.0	Scale score 513 Level 3
Incorrect		21.6	25.7	
Missing		9.9	17.3	
Overall correct	*(Partial credit responses weighted by 0.5)*	45.7	35.6	

Educational Research Centre
Dublin 9

http://www.erc.ie

ISBN 0-900440-24-4