Future Ready?

The Performance of 15-year-olds in Ireland on Science, Reading Literacy and Mathematics in PISA 2015

Gerry Shiel, Cathy Kelleher, Caroline McKeown and Sylvia Denner

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Preface

The Programme for International Student Assessment (PISA) is an assessment of the skills and knowledge of 15-year-olds in science, reading literacy and mathematics. It is sponsored by the Paris-based Organisation for Economic Cooperation and Development (OECD). The first three-yearly PISA cycle was in 2000. PISA 2015 is the sixth. In each cycle, one domain is designated a major domain, and the remaining domains function as minor domains. In PISA 2015, science was the major assessment domain, while reading literacy and mathematics were minor domains.

2015 marked a milestone in the development of PISA. While earlier cycles had offered optional computer-based tests (Ireland took part in digital reading in 2009 and 2012, and in computer-based mathematics and problem solving in 2012), 2015 marked the first cycle in which most participating countries, including all 35 OECD member countries, took the core parts of PISA on computer. 2015 was also significant in that PISA was implemented by a new consortium on behalf of the OECD – the Educational Testing Service in the United States. Previous cycles had been implemented by the Australian Council for Educational Research (ACER). PISA 2015 also marked the first cycle in which parents of participating students in Ireland completed a questionnaire.

PISA 2015 was implemented in 72 countries/economies, including all 35 OECD member countries, with tests and questionnaires completed by 535,791 students. In Ireland, 5,741 students in 167 schools took part, with the majority of participants in Third year and Transition year, and smaller proportions in the Second and Fifth years.

The OECD (2016a) has published a framework for PISA 2015 that outlines the content of tests and the questionnaires. Two reports will be published to coincide with the launch of the PISA 2015 results: *PISA 2015 Results (Vol. 1): Excellence and Equity in Education* (OECD, 2016b) and *PISA 2015 Results (Vol. 2): Policies and Practices for Successful Schools* (OECD, 2016c). A third report, *Results (Vol. 3): Students' Well-being,* will be published in April 2017. A technical report on PISA 2015 is also being prepared (OECD, in press).

This current report, which provides an overview of the main outcomes of PISA 2015 as they relate to Ireland, is the first in a series of national reports based on the 2015 cycle. Others will focus on students' home environments and learning (drawing on the PISA parent questionnaire and other data sources) and on students' uses of ICT. A report that integrates the findings of the Trends in International Mathematics and Science Study (TIMSS) in which students in Second year in Ireland took part in 2015, and PISA is also planned.

This report is divided into nine chapters. Chapter 1 provides an overview of the PISA framework and the design of PISA 2015. Chapter 2 summarises performance on previous cycles, and describes the broader context in which PISA 2015 was implemented. Chapter 3 looks at existing research on computers and test performance and previous computer-based assessments offered as part of PISA. Chapter 4 describes performance in PISA 2015 on science, while Chapter 5 describes performance on reading literacy and mathematics. Chapter 6 describes background factors associated with performance on PISA 2015 at the student and school levels, while Chapter 7 describes students' engagement, motivation and attitudes towards science. Chapter 8 compares performance and other outcomes in 2015 with those from earlier PISA cycles. A summary and conclusions are presented in Chapter 9.

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We would like to thank all those involved in implementing the PISA 2015 Field Trial in spring 2014, and the Main Study in spring 2015. These include: the principal teachers and school contact persons who facilitated the involvement of their schools in PISA; the members of the Inspectorate and retired inspectors, principals and teachers who administered PISA in schools; Carmel Donohue of the Inspectorate who helped with the organisation of training sessions for test administrators and with the organisation of PISA in schools; the technical support persons who helped to ensure that the technology was in good working order at all times; students' parents who completed a Parent Questionnaire for the first time as part of PISA, and last, but not least, the students who completed the assessments, without whom PISA would not be possible.

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Acronyms and Abbreviations

ACER	Australian Council for Educational Research
CBA	Computer-based Assessment
CBAS	Computer-based Science (in PISA 2006)
DEIS	Developing Equality of Opportunity in Schools
DES	Department of Education and Skills
ECCE	Early Childhood Care and Education (Scheme)
ERC	Educational Research Centre
ESCS	Economic, Social and Cultural Status
ETS	Educational Testing Service
FT	Field Trial
GMO	Genetically Modified Organism
ICT	Information and Communication Technology
IRT	Item Response Theory (Scaling)
NAEP	National Assessment of Educational Progress (US)
NCCA	National Council for Curriculum and Assessment
OECD	Organisation of Economic Cooperation and Development
PBA	Paper-based Assessment
PIAAC	Programme for the International Assessment of Adult Competencies
PISA	Programme for International Student Assessment
SEC	State Examinations Commission
STEM	Science, Technology, Engineering and Mathematics
TIMSS	Trends in International Mathematics and Science Study
2PL	2 Parameter Logistic (Model)

Executive Summary

The Programme for International Student Assessment (PISA) is a project of the Organisation for Economic Cooperation and Development (OECD), of which Ireland is a member. PISA, which has taken place every three years since 2000, assesses the preparedness of 15-year-olds to meet the challenges they may encounter in their future lives, including their future education (OECD, 2016a). In 2015, over 500,000 15-year-olds in 72 countries/economies took part in PISA,[1] including all 35 OECD countries. Science was the major assessment domain in 2015, with reading literacy and mathematics designated as minor domains. In Ireland, PISA is implemented by the Educational Research Centre, on behalf of the Department of Education and Skills.

Changes to PISA in 2015

In earlier assessment cycles, the main PISA tests were administered on paper in all participating countries, while some computer-based testing was conducted on an experimental basis in subsets of countries. In 2015, most participating countries, including all 35 OECD-member countries, administered the main tests (and questionnaires) on computer. Drawing on data from the PISA 2015 Field Trial (administered in 2014), the OECD and its contractors investigated whether performance on computer-based tests in 2015 could be linked back to earlier paper-based scales, thereby maintaining trend lines. The mode-effect study, which used pooled data across countries, concluded that a link back to earlier paper-based cycles could be maintained (OECD, 2016b).

In addition to the change in assessment mode in PISA 2015, significant changes were introduced into the test design and scaling of student performance. Changes to the test design involved increases in the proportions of items assessed in the minor domains, and in the proportions of students who completed one hour of testing on each of the minor domains, compared with earlier cycles. These changes were intended to improve construct coverage, as well as provide a more coherent experience for test takers. There were also changes in scaling related to the size of the calibration sample, the scaling model, the treatment of items that function differentially across countries, and the treatment of not-reached items during scoring. While many of these changes may well improve the stability and accuracy of scores in future PISA cycles, they complicate the interpretation of scores in PISA 2015.

Implementation of PISA 2015 in Ireland

PISA 2015 was implemented in Ireland in March 2015. A representative sample of 169 schools was selected to take part, and, of these, 167 participated, giving a weighted response rate of 99.3%. Within each school, up to 42 students who met the age-based criterion (born in 1999) were selected to take part. In all, 5,741 students completed PISA, yielding a weighted student response rate of 88.6%, after ineligible students and students with special needs had been accounted for. The students were distributed over four grade levels – Second year (1.9%), Third year (60.5%), Transition year (26.7%), and Fifth year (10.9%). Across grade levels, 48.7% of students were females and 51.3% were males.

PISA was administered in schools by members of the inspectorate of the Department of Education and Skills and by staff of the Educational Research Centre. Students completed the assessment on laptop computers, brought to schools and installed by technical support persons. A typical PISA assessment session took over 3.5 hours, and includes an orientation module, two one-hour slots

[1] Of these, 70 had gathered achievement data that could be compared across countries.

allocated to the computer-based tests of science, reading literacy and mathematics in various combinations, and about an hour to computer-based student questionnaires. Principal teachers and science co-ordinators in participating schools, and parents of participating students also completed questionnaires. Tests and questionnaire items were scaled by the OECD's contractors, and the weights to be applied to student responses were computed by them.

Performance on Science in PISA 2015

Ireland's mean score on the overall science literacy scale (502.6) in PISA 2015 is significantly higher than the OECD average (493.2), and is also significantly higher than the mean scores of 45 PISA-participating countries/economies. Ireland's science performance ranks 13th among all OECD countries, and 19th among the 70 PISA-participating countries and economies with valid data. With a 95% confidence interval applied, Ireland's true rank in science lies between 11th and 18th in the OECD, and between 17th and 24th among all participating countries and economies. The highest performing country/economy overall in science is Singapore, which, with a mean score of 555.6, significantly outperforms all other countries/economies. The next highest performers are Japan (538.4), Estonia (534.2), Chinese-Taipei (532.3) and Finland (530.7). Performance on science in Ireland does not differ significantly from the performance of the United Kingdom, Germany, the Netherlands, Switzerland, Belgium, Denmark, Poland, Portugal, Norway, the United States. Mean performance in Northern Ireland (500.0), a region of the United Kingdom in PISA, is not significantly different from that of Ireland.

The range in science achievement in Ireland (the difference between the 95th and 5th percentiles) is 291.9 points, which is significantly narrower than the average of 308.7 points across OECD countries.

Ireland has fewer lower-performing students – those scoring below Proficiency Level 2 (15.3%) – compared with the OECD average of 21.2%. Countries with lower proportions of students than Ireland below Level 2 include Estonia (8.8%), Japan (9.6%), Singapore (9.6%), Canada (11.1%) and Finland (11.5%). The proportion of high performers – those scoring at Proficiency Level 5 or above – is about the same in Ireland (7.1%) as on average across OECD countries (7.7%). Countries with higher proportions of students than Ireland performing at these levels include Singapore (24.4%), Japan (15.3%), Finland (14.3%), Estonia (13.5%) and New Zealand (12.8%).

PISA 2015 assessed key competencies and knowledge for science literacy using eight overlapping subscales derived from the overall science scale. Ireland's mean score is significantly higher than the corresponding OECD average score on all three science competency subscales, with a relative strength on Explain Phenomena Scientifically, compared with Evaluate and Design Scientific Enquiry and Interpret Data and Evidence Scientifically. Ireland's mean scores on the Content Knowledge and Procedural and Epistemic Knowledge subscales are also higher than the corresponding OECD average scores. Students in Ireland also perform above the corresponding OECD averages on Physical Systems, Living Systems and Earth and Space Systems, with performance on Physical Systems identified as an area of relative strength.

Male students in Ireland significantly outperform female students by 10.5 score points on overall science, while on average across OECD countries, the difference in favour of male students is a significant 3.5 score points. Male students also perform significantly higher than females in the United States (by 6.8 points), Germany (by 10.5), and Japan (by 13.6). However, in Finland, female students score significantly higher on science than males by 19 score points. Similar percentages of male (15.7%) and female (14.9%) students in Ireland perform below Level 2 on overall science, but more males (9.0%) than females (5.0%) perform at or above Level 5. Similarly, on average across

OECD countries, equivalent percentages of males (21.8%) and females (20.7%) perform below Level 2, while more males (8.9%) than females (6.5%) perform at or above Level 5. Hence, the OECD average proportions below Level 2 are higher than in Ireland for both males and females, while equivalent proportions of males and females in Ireland, compared with the corresponding OECD averages, perform at Level 5 or above.

Male students in Ireland significantly outperform their female counterparts on two of three science competencies (Explain Phenomena and Interpreting Data and Evidence), on one of two knowledge subscales (Content Knowledge), and on all three science knowledge systems (Physical Systems, Living Systems and Earth and Space Systems). The largest differences are on Explain Phenomena (17.2 points), Content Knowledge (17.5) and Physical Systems (11.1). Average differences across OECD countries also tend to favour male students, though to a lesser extent than in Ireland. On average across OECD countries, differences between competency, knowledge and systems subscales are small, though, as in Ireland, students perform marginally better on Physical Systems compared with other content systems.

Performance on Reading Literacy in PISA 2015

Students in Ireland achieved a mean score of 520.8 on reading literacy, which as significantly above the OECD average of 492.5. Ireland ranks 3rd of 35 OECD countries, and 5th among all participating countries/economies. Applying a 95% confidence interval, Ireland's 'true rank' is between 2nd and 6th among OECD countries, and between 4th and 8th among all participating countries. Only Singapore has a significantly higher mean score (535.1) than Ireland, while students in Ireland do not differ significantly in average performance from students in Hong-Kong China, Canada, Finland, Estonia, Korea or Japan. The mean reading score for Northern Ireland (497.0) is significantly below the mean score for Ireland, and is not significantly different from the OECD average.

The range in reading achievement in Ireland (the difference between the 95th and 5th percentiles) is 283.6 points, which is significantly narrower than on average across OECD countries (315.4).

Just 10.2% of students in Ireland perform at the lowest levels of reading proficiency (below Level 2) – about the same as in other high-performing countries including Estonia (10.6%), Canada (10.7%), Finland (11.1%) and Singapore (11.1%). On average across OECD countries, one-in-five students (20.1%) perform below Level 2. In Ireland, 10.7% of students perform at the highest proficiency levels in reading (Levels 5-6). This is about the same as in Germany (11.7%), Estonia (11.0%) and Sweden (10.0%), but lower than in Singapore (18.4%), Canada (14.0%) and Finland (13.7%). On average across OECD countries, 8.3% perform at Levels 5-6 in reading.

In Ireland, female students significantly outperform male students on reading literacy, by 12.0 score points. This compares favourably with the average gender difference of 26.9 points in favour of females across OECD countries. Countries with larger gender differences than Ireland include Finland (46.5), Korea (40.5), Sweden (39.2) and New Zealand (32.3). In Ireland, 8.0% of females and 12.3% of males perform below Proficiency Level 2, compared with 15.6% and 24.4% on average across OECD countries. Equal percentages of female and male students in Ireland (10.7%) perform at Levels 5-6, compared with OECD average percentages of 9.9% (females) and 6.8% (males).

Performance on Mathematics in PISA 2015

In PISA 2015 mathematics, students in Ireland achieved a mean score of 503.7, and a ranking of 13th of 35 OECD countries, and 18th of 70 participating countries/economies. Applying a 95% confidence interval, Ireland's true rank lies between 10th and 14th among OECD countries, and between 15th and 19th among participating countries. Ireland's mean score is significantly above the OECD average score of 490.2. Fourteen countries/economics have significantly higher mean scores than Ireland including Singapore (which outperforms all other participating countries/economies), Hong-Kong China, Japan, Korea, Switzerland, Estonia and Canada. Countries that perform at about the same level as Ireland include Belgium, Germany, Poland, Norway and Austria. Countries with significantly lower mean scores than Ireland include New Zealand, Australia, the United Kingdom, Israel and the United States. Northern Ireland's mean score (493.8) is not significantly different from Ireland's mean score, or from the OECD average score.

The range in mathematics achievement in Ireland (the difference between the 95th and 5th percentiles) is 261.9 points, which is significantly smaller than the corresponding average of 293.3 across OECD countries, indicating a narrower range of performance in Ireland.

In Ireland, 15.0% of students perform at the lowest levels of mathematics proficiency (below Level 2), compared with an OECD average of 23.4%, indicating low performance. A number of countries including Singapore (7.6%), Japan (10.7%) and Estonia (11.2%) have fewer students than Ireland performing below Level 2. Just 9.8% of students in Ireland perform at the highest proficiency levels (Levels 5-6). The corresponding OECD average is marginally higher at 10.7%. A number of countries have significantly higher percentages of students performing at Levels 5-6, including Singapore (34.8%), Korea (20.9%) and Japan (20.3%).

The mean mathematics score of male students in Ireland (511.6) is significantly higher than the mean score of female students (495.4). Among a set of comparison countries, only Germany (16.6 points) has a difference in favour of male students that is similar to Ireland's (16.1). On average across OECD countries, male students significantly outperform female students by 7.9 score points. In Korea, female students have a mean score that is higher than that of males (by 7 score points), but the difference is not statistically significant. In Ireland, 14.1% of males and 15.8% of females perform below Proficiency Level 2 in mathematics, compared with 23.0% and 23.7% on average across OECD countries. Almost twice as many male students in Ireland perform at Proficiency Levels 5-6, compared with female students (12.9% vs. 6.5%). On average across OECD countries, more male students (12.9%) than female students (8.9%) perform at Levels 5-6.

Student- and School-level Associations with Achievement in PISA 2015

Data were gathered on a range of student and school background characteristics in PISA 2015 and their relationships to achievement were examined. At the student level, Economic, Social and Cultural Status (ESCS) is a strong predictor of achievement in all domains in Ireland and on average across OECD countries. In Ireland, students in Transition year have higher ESCS than students in all other grades assessed, and outperform students in the other grades on science, reading and mathematics. Students who attended pre-school (83.8%) also have higher ESCS. Pre-school attendance is positively associated with achievement across domains, while skipping school and being late for school are negatively associated with achievement. Students in Ireland have greater interest in Information and Communication Technology (ICT), and feel more competent and autonomous in its use, but they use ICT less often at school and at home for schoolwork compared to students on average across OECD countries. Almost three-in-five (57.2%) students in Ireland, and more females (60.5%) than males (54.0%), had never taken a computer-based test prior to PISA 2015.

At the school level, average school ESCS is significantly related to students' achievement in science, reading and mathematics. Differences in achievement also exist on the basis of school type, school fee-paying status and school participation in the Schools Support Programme (SSP) under DEIS. A better disciplinary climate in science class, as reported by students in Ireland, is associated with higher scores on science when school and student ESCS are taken into account, while greater perceived feedback from science teachers is associated with lower scores. Students in Ireland on average report similar frequencies of specific teaching practices in science class (adaptive instruction, inquiry-based instruction, and teacher-directed science instruction) as students across OECD countries on average. Greater frequencies of adaptive instruction and teacher-directed science instruction are associated with higher scores in science among students in Ireland. Some aspects of inquiry-based instruction (e.g., teachers clearly explaining the relevance of science concepts to students' lives) have positive associations with performance in science, while other aspects (e.g., students being allowed to design their own experiments) have negative associations. Compared to OECD countries on average, principals and parents in Ireland report greater efforts by schools to involve parents. Parents in Ireland report less participation in school-related activities than parents on average across OECD countries. Participation in some school-related activities, such as discussing a child's progress on the initiative of their teacher, is negatively associated with achievement, after accounting for student and school ESCS. However, participation in 'a scheduled meeting or conference for parents' is associated with a 10-point advantage on science for students of participating parents in Ireland relative to non-participating parents.

Students' Engagement, Motivation and Attitudes towards Science in 2015

Around eight out of ten students in Ireland, and more female students than male students, study or intend to study a science subject to Leaving Certificate level. However, fewer than one-third of students in Ireland expect to be in a science-related career at age 30. Among those expecting a career in science, health-care professions such as nursing, physiotherapy and medicine are the most popular choices. Students in Ireland, and across OECD countries on average, report infrequent participation in science-related activities inside or outside of school. However, participation in science-related activities is significantly associated with achievement in science. When students in Ireland engage with science activities, it tends to be via the Internet more so than through books or magazines, or though science clubs, and participation in science activities is significantly higher among male students than female students.

Students in Ireland report greater enjoyment of science (intrinsic motivation) and greater interest in science topics (e.g., how science can help prevent disease) than do students on average across OECD countries. In Ireland, male students report more intrinsic motivation for science learning than female students, but they do not differ from female students in how useful they perceive science to be for their future study and career plans (instrumental motivation). Students in Ireland have greater instrumental motivation for science learning than do students on average across OECD countries. Scores on the motivation indices have positive associations with performance in science among students in Ireland, with correlations in the moderate[2] (Enjoyment of Science and Interest in Science Topics) and weak-to-moderate (Instrumental Motivation) ranges.

[2] Correlation coefficients between .26 and .40 are considered moderate, and those between .11 and .25 are considered weak-to-moderate.

In Ireland, performance on PISA science is significantly associated with Science Self-efficacy (students' beliefs in their ability to use scientific knowledge to complete real world science tasks), and with students' Epistemic Beliefs (the extent to which students value scientific approaches to enquiry). Ireland's score on Science Self-efficacy does not differ significantly from the OECD average. However, students in Ireland score well above the OECD average on Epistemic Beliefs and have one of the higher mean scores on the scale among all participating countries/economies. In Ireland, male students score significantly higher on Science Self-efficacy than female students, but male students and female students do not differ significantly on Epistemic Beliefs. Students in Ireland also score above the OECD averages on indices of Environmental Awareness and Environmental Optimism, indicating that they have a higher degree of familiarity with various environmental issues such as air pollution, and are more optimistic about improvements in these issues. However, Environmental Optimism is not positively related to achievement in science.

Trends in Science Performance

The difference in performance in Ireland between 2006 and 2015 (the OECD's preferred comparison window)[3] of 5.8 score points is not statistically significant. The OECD average difference fell by a non-significant 4.8 score points. Several countries experienced significant negative changes in this period, including Finland (-32.7), New Zealand (-17.1), and Austria (-15.8).

On average across OECD countries, there was a significant drop of 8.0 score points in science performance between 2012, when science was a 'minor domain', and 2015, when it was a 'major domain'. Only Portugal showed a significant improvement. Ireland's mean score decreased by 19.4 score points between 2012 and 2015, which is significant, as did the mean scores of Hong Kong (China) (-31.7), Poland (-24.4), and Korea (-22.0), and seven other comparison countries.

The analysis of trends by proficiency level and by gender provides information on areas of relative strength and weakness in science performance – both between 2006 and 2015 and between 2012 and 2015. In Ireland, the percentage of students performing below Level 2 ('low' performers in science) remained relatively stable, at 15.5% in 2006, and 15.3% in 2015, though, in 2012, just 11.1% performed below Level 2. In contrast, the proportion of students in Ireland performing at or above Proficiency Level 5 ('high' performers) decreased to 7.1% in 2015 from 9.4% in 2006, and 10.7% in 2012. There are fewer higher performers in science in Ireland in 2015, compared with 2006 and 2012.

In 2006, female students in Ireland had a mean score that was higher than male students by a non-significant 0.4 score points. In PISA 2015, there was a 10.5 points difference in favour of male students. The corresponding OECD average in 2015 is 3.5 score points in favour of males. Linked to this, similar proportions of male and female students in Ireland performed below Level 2 in both 2006 (16.5% of males and 14.5% of females) and 2015 (10.3% and 8.5% respectively). However, while similar proportions of males (10.3% in 2006 and 9.0% in 2015) performed at Level 5 or above, significantly fewer females did so (8.5% and 5.0% respectively).

The difference in science performance between 2012 and 2015 needs to be considered in the context of the changes made in PISA in 2015, including the transition to computer-based testing in most participating countries, the introduction of new, more interactive items that require students to perform virtual experiments and respond to questions that assess their understanding of the outcomes, and changes to the PISA's design and scaling procedures. It is surprising that the scores of

[3] According to the OECD (2016b), it is safer to compare performance from 'major' to 'major' (2006-2015 in the case of science) than from 'minor' to 'major' (2012-2015 for science).

higher-performing students seem to have been affected by the transition to computer-based assessment to a greater extent than those of lower-performing students. It may be that the transition to computer rendered higher-level questions in PISA more challenging, while leaving lower-order ones at the same level as previously.

Trends in Reading Literacy Performance

Reading literacy was a minor assessment domain in PISA 2015. Ireland's mean score increased substantially between 2009 (the last cycle in which it was a major domain) and 2012, returning to the level achieved between 2000 and 2006. Ireland's mean score was marginally, but not significantly, lower (by 2.4 score points) in 2015, compared with 2012. It is notable that just five countries experienced significant declines in reading performance between 2012 and 2015, including Japan (-22.1), Korea (-18.4), and Switzerland (-16.8), while three had significant increases – Slovenia (23.9), the Russian Federation (35.2) and Sweden (16.8).

While female students in Ireland and on average across OECD countries performed significantly better than males on PISA 2015 reading, the gender gap in Ireland was smaller in 2015 (12.0 score points) than in 2012 (28.5) or in earlier cycles and is now well below the average across OECD countries (27.1 score points in 2015, down from 39.3 in 2012). Hence, the gender gap narrowed both in Ireland and on average across OECD countries in the course of transitioning to computer-based testing (albeit with the same texts that appeared on paper in earlier cycles). In 2015, 3.7% fewer female students performed at Level 5 or above, compared with 2012. There was an increase of 2.2% in the proportion of males performing at Level 5 or above between these years.

The relatively-strong performance of students in Ireland on reading literacy is not unexpected. In PISA 2012, students in Ireland did well on an experimental test of computer-based literacy. Furthermore there is evidence of improved performance at primary level (Shiel & Kavanagh, 2014). While, on the one hand, it is encouraging to see male students performing more strongly in reading literacy in 2015 than in earlier cycles, when the test was mainly offered on paper, the finding that fewer female students achieved Levels 5-6 relative to earlier cycles needs to be considered by policy-makers, perhaps in the context of the broader move towards computer-based teaching, learning and assessment described in the *Digital Strategy for Schools* (DES, 2015b).

Trends in Mathematics Performance

PISA 2015 was the first cycle in which all participating students in Ireland had studied under the new mathematics curriculum for Junior Certificate and Leaving Certificate, colloquially known as 'Project Maths'. However, it is difficult to gauge the impact of the new curriculum on performance, given the other changes to PISA in 2015, including the transition to a computer-based platform. Mathematics was a minor assessment domain in 2015.

Ireland's mean scores on PISA mathematics in 2003 (502.8) and 2006 (501.5) were not significantly different from the corresponding OECD averages. In 2009, Ireland's mean score (487.1) was significantly below the OECD average. In 2012, when it increased to 501.5, it was significantly above the OECD average for the first time, and in 2015, it improved slightly, to 503.7, and maintained its position relative to the OECD average. Ireland's relatively stable performance between 2012 and 2015 is remarkable in that 8 of the top 30 highest-performing countries in 2012 experienced declines in 2015, including Korea (-29.7), Hong Kong (China) (-13.3), Poland (-13), the Netherlands (-10.7) and Australia (-10.3), and five experienced significant increases, including Sweden (+15.7), Norway (+12.4) and Denmark (+11.1). As with reading literacy, it is unclear if the transition to computer-based assessment is responsible for these changes, and, if so, why.

In 2015 in Ireland, there was a gender gap of 16.1 score points in favour of male students in mathematics, up from 15.3 points in 2012, and well above the OECD average of 7.7 (which fell back from 10.3 in 2012). Indeed, in 2015, in contrast with the situation in reading, Ireland had one of the largest gender gaps in mathematics among OECD countries. Again, it is notable that just 6.5% of female students in Ireland performed at or above Level 5 on mathematics, down from 8.5% in 2012 (when mathematics was a 'major domain'), and well below the OECD average of 9.0% in 2015, which itself dropped from 10.8% in 2012. In 2015, there was a slight increase in the proportion of male students in Ireland performing at Level 5 or above compared with 2012 (12.7% to 12.9%), while on average across OECD countries, there was significant drop between these years, from 14.9% in 2012 to 12.6% in 2015.

There was a drop of 4.8 points in Ireland's standard deviation in mathematics between 2012 and 2015, and it is now 79.8 points – well below the OECD average of 98.4.

It may be that Ireland's relatively stable performance on PISA mathematics between 2012 and 2015 can be attributed to the knowledge and skills that students acquired through their participation in the new mathematics curriculum ('Project Maths'), enabling them to better handle the requirements of PISA mathematics than their counterparts in earlier PISA cycles, despite the move to computer-based testing. Again, however, the widening gender gap in mathematics is notable. Factors associated with this may include female students' ongoing difficulties with the Shape and Space component of PISA mathematics (though many male students struggle with this too), their higher levels of anxiety about mathematics (Perkins et al., 2013) and the challenges posed by computer-based testing.

Trends in School and Student Characteristics

In general, the characteristics of the PISA 2015 sample in Ireland were found to be similar to those of earlier PISA cycles. However, there was a notable increase in the proportion of students described as immigrant speakers of English or Irish (up from 3.6% in 2006 to 7.3% in 2015) and immigrant speakers of other languages (up from 1.7% to 7.1% between the same years), though the latter group may have included some exchange students from other EU countries who were studying in Ireland for part of the 2014-15 school year. The proportion of students in Transition year also increased, from 21.2% in 2006 to 26.7% in 2015, with a parallel fall in the proportion in Fifth year (from 17.5% to 10.9%). When the OECD reweighted Ireland's data for previous PISA cycles to the observed composition of the PISA 2015 sample, the revised mean scores were close to the original estimates, suggesting that demographic change had little impact on performance across cycles.

The proportions studying science in the Junior Certificate examination increased from 82.6% in 2006 to 91.2% in 2015. Further, among those taking science, the proportion taking the Higher-level science paper increased from 67.3% in 2006 to 78.6% in 2015. There is no clear evidence that any of these changes impacted in a negative way on PISA science performance in Ireland between 2012 and 2015.

Trends in Students' Engagement, Motivation and Attitudes towards Science

Students in Ireland report a large and significant increase in their Enjoyment of Science between 2006 and 2015 and Ireland's mean score on this index is now significantly above the OECD average. It is noteworthy that Instrumental Motivation to learn science has increased significantly, perhaps because students are more aware of the importance of science in the context of their future careers. Although there has been an increase in Ireland's mean score on the PISA index of Science Activities, it still lags behind the corresponding OECD average score, and students in Ireland continue to report low involvement in activities such as visiting web sites about science topics, reading science magazines, and attending science clubs. There has been a small but significant increase, from 23.8% in 2006 to 27.3% in 2015, in the proportion of students in Ireland expecting to be in science-related occupations by age 30. Roughly equivalent proportions of male (28.0%) and female students (26.6%) expect to work in these occupations, with more male students expressing a preference for engineering and ICT careers, and more females favouring a career as a health professional.

Chapter 1: Overview and Implementation of PISA 2015

The Programme for International Student Assessment (PISA) is a project of the Organisation for Economic Co-operation and Development (OECD) that aims to measure how well students, at age 15[4], are prepared to meet the challenges they may encounter in future life, including education (OECD, 2016a). At age 15, students in most OECD countries are approaching the end of compulsory education. While PISA is informed by the content of national curricula, the focus of the assessment is on students' ability to apply knowledge and skills effectively in unfamiliar, real-life situations.

PISA takes place every three years and assesses students in the three domains of reading literacy, mathematical literacy and science literacy[5]. Previous cycles of PISA were primarily paper-based, though, from 2006 onwards, experimental assessments of digital reading, computer-based mathematics, science, and problem solving were included on an optional basis. The current (2015) cycle of PISA is the first one in which the vast majority of countries implemented PISA using computer only (see Chapter 3).

Each cycle of PISA focuses on one 'major domain', to which a majority of testing time is devoted. The 'minor domains' provide a less detailed profile of achievement. Science was the major domain for the second time in PISA 2015 (see Table 1.1). Therefore, it provides the first opportunity for a detailed examination of changes in science outcomes since 2006. Ireland did not take part in two optional assessments that were available in PISA 2015 – computer-based collaborate problem solving and financial literacy.

Table 1.1. Assessment domains across PISA cycles (2000-2012)

Year	Major domain	Minor domain
2000	Reading	Mathematics, Science
2003	Mathematics	Reading, Science, Problem Solving
2006	Science	Mathematics, Reading
2009	Reading	Mathematics, Science
2012	Mathematics	Reading, Science, Problem Solving, Financial Literacy
2015	Science	Mathematics, Reading, Computer-based Collaborative Problem Solving, Financial Literacy

Over 500,000 students in 73 countries/economies[6] (listed in Table 1.2) participated in the main strand of PISA 2015, i.e. the tests of science, mathematics and reading literacy. Among the 70 countries with internationally-comparable data, students in 56 countries/economies completed the tests on computer only, while the remainder (all non-OECD-member countries) completed the paper-based version.

[4] The PISA population in a country is defined as all students enrolled in educational programmes aged between 15 years and 3 months, and 16 years and 2 months (OECD, 2013b). For PISA 2015 in Ireland, this meant that students born in 1999 were eligible to take part.

[5] Throughout this report, the terms mathematical literacy and science literacy are abbreviated to mathematics and science.

[6] Not all participating entities are countries (e.g., the Chinese cities of Beijing, Shanghai, Jiangsu and Guangdong).

This chapter is organised in seven main sections. The first three describe the content of the assessments of science, reading literacy and mathematics respectively, including changes from previous cycles; the fourth considers the content of questionnaires that were administered to participating students, school principals and parents in order to generate contextual information; the fifth describes the implementation of PISA 2012 in Ireland; the sixth provides information on the PISA test design and the scaling of PISA, including changes from earlier cycles; and the seventh provides information on interpreting the analyses in this report.

Table 1.2. Countries/economies participating in PISA 2015

OECD Countries		Partner Countries/Economies	
Australia	Latvia*	Albania (PBA)	Lebanon (PBA)
Austria	Korea, Republic of	Algeria (PBA)	Macao-China
Belgium	Luxembourg	Argentina** (PBA)	FYRO Macedonia (PBA)
Canada	Mexico	Brazil	Malaysia (PBA)
Chile	Netherlands	Bulgaria	Malta (PBA)
Czech Republic	New Zealand	China (B-S-J-G)***	Moldova (PBA)
Denmark	Norway	Chinese Taipei	Montenegro
Estonia	Poland	Colombia	Peru
Finland	Portugal	Costa Rica	Qatar
France	Slovak Republic	Croatia	Romania (PBA)
Germany	Slovenia	Cyprus	Russian Federation
Greece	Spain	Dominican Republic	Singapore
Hungary	Sweden	Georgia (PBA)	Thailand
Iceland	Switzerland	Hong Kong-China	Trinidad and Tobago (PBA)
Ireland	Turkey	Indonesia (PBA)	Tunisia
Israel	United Kingdom	Jordan (PBA)	United Arab Emirates
Italy	United States	Kazakhstan (PBA)	Uruguay
Japan		Kosovo (PBA)	Vietnam (PBA)
		Lithuania	

*Latvia became a full OECD member on July 1, 2016; **Autonomous cities only appear in tables;

***Beijing-Shanghai-Jiangsu-Guangdong. PBA: Paper-based assessment. All other countries including Ireland administered PISA on computer (CBA). Kazakhstan and Malaysia do not appear in the tables of mean scores in Chapters 4 and 5 because the quality of their data was not deemed to have reached the required level by the OECD and its contractors.

The PISA tests comprise assessment units consisting of stimulus material (text and other information such as tables, charts, graphs and diagrams) followed by one or more items that are based on the stimulus material. In PISA 2015, for the first time, stimulus materials in science included interactive items, where students were asked to simulate experiments by controlling for a number of variables at the same time and evaluating outcomes with reference to the question being asked (see Appendix B).

The assessment features both selected-response (multiple-choice) and constructed-response type item formats. Multiple-choice items are either simple multiple-choice, requiring students to select an answer from a number of alternatives, or complex multiple-choice, in which students are asked to choose between two possible responses (e.g., yes or no) to a series of statements. Constructed-response items are designed to elicit a typed response from students, which may be long or short depending on the context. Examples of different response options for science are presented in Appendix B.

The theoretical basis of each domain is articulated in a set of assessment frameworks, which also serve to guide test development (OECD, 2016a). Though the framework for each domain differs from the others, all are similarly structured in that each one describes the type of *content or knowledge* it encompasses, the *processes* required of students, and the *situations/contexts* in which assessment items are situated. The following sections summarise the frameworks for science, reading and mathematics respectively.

1.1. Framework for Science

This section describes the definition of science used in PISA 2015, the range of science competencies assessed, the types of scientific knowledge examined, the content knowledge systems assessed, the contexts of the assessment items, the science attitudes assessed, and a breakdown of the item types used in 2015.

1.1.1. Definition of scientific/science literacy

Scientific literacy in PISA 2015 is defined as:

> the ability to engage with science-related issues, and with ideas of science, as a reflective citizen. A scientifically-literate person, therefore, is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically (OECD, 2016a, p. 20).

PISA uses the terms 'scientific literacy' or 'science literacy' rather than science to underscore the focus on the application of scientific knowledge in the context of life situations. Reference is made to the 'scientifically literate citizen' who has 'a knowledge of the major conceptions and ideas that form the foundation of scientific and technological thought, how such knowledge has been derived, and the degree to which such knowledge is justified by evidence or theoretical explanation' (OECD, 2013, p. 4). It is significant that PISA science literacy incorporates both science and science-based technology. This recognises the relationship between science and technology, where progress in science (scientific knowledge) can feed into technology and vice versa.

1.1.2. Range of science competencies

Science literacy in PISA 2015 is defined by three competencies or basic sets of practices that are considered essential:

- ***Explain phenomena scientifically*** – recognise, offer and evaluate explanations for a range of natural and technological phenomena, demonstrating the ability to:
    - Recall and apply appropriate scientific knowledge
    - Identify, use and generate explanatory models and representations
    - Make and justify predictions
    - Offer explanatory hypotheses
    - Explain the potential implications of scientific knowledge for society.
- ***Evaluate and design scientific enquiry*** – describe and appraise scientific enquiries and propose ways of addressing questions scientifically demonstrating ability to:
    - Identify the question explored in a given scientific study
    - Distinguish questions that are possible to investigate scientifically
    - Propose a way of exploring a given question scientifically
    - Identify whether appropriate procedures have been used
    - Evaluate ways of exploring a question scientifically

    - Describe and evaluate a range of ways that scientists use to ensure the reliability of data and the objectivity and generalisability of explanations.

- ***Interpret data and evidence scientifically*** – analyse and evaluate scientific information, claims and arguments in a variety of representations and draw appropriate conclusions by demonstrating the ability to:

    - Transform data from one representation to another
    - Analyse and interpret data and draw appropriate conclusions
    - Identify assumptions, evidence and reasoning in science-related texts
    - Distinguish between arguments which are based on scientific evidence and theory and those based on other considerations
    - Evaluate scientific arguments and evidence from different sources (e.g., newspaper, Internet, journal).

1.1.3. Types of scientific knowledge

All three competencies require knowledge. According to the framework, three types of 'related but distinguishable' knowledge are required:

- ***Content Knowledge*** – a knowledge of the facts, concepts, ideas and theories about the natural world that science has established. This knowledge is mainly used in explaining phenomena scientifically. Three content areas – Physical Systems, Living Systems and Earth and Space Systems – are equally represented among PISA science items

- ***Procedural Knowledge*** – knowledge of the features that characterise scientific enquiry, that is the diverse methods and practices used to establish scientific knowledge

- ***Epistemic Knowledge*** – an understanding of the rationale for the common practices of scientific enquiry, the status of the knowledge claims that are generated, and the role that questions, observations, theories, hypotheses, models and arguments play in science.

It might be noted that, for reporting purposes in PISA 2015, Procedural and Epistemic knowledge areas were combined to create a single subscale, Procedural and Epistemic Knowledge.

1.1.4. Content knowledge systems

In addition to classifying items by type of scientific knowledge, all items were classified in terms of the main knowledge system drawn on:

Physical Systems – these items draw on knowledge of the structure and properties of matter, including its chemical properties, chemical reactions, motion and forces (e.g., velocity and friction), magnetic fields, energy and its transformation (e.g., conservation, dissipation), and interactions between energy and matter.

Living Systems – these draw on knowledge of the cell and its structures (e.g., DNA), the concept of an organism (uni- vs. multi-cellular), human biology, populations (e.g., species and their evolutionary dynamics), and ecosystems and the biosphere.

Earth and Space Systems – these draw on knowledge about the structure of earth systems (e.g., atmosphere), changes in earth systems (e.g., plate tectonics, geothermal cycle), the earth's history, earth in space (gravity, solar systems, galaxies), and the history and scale of the universe.

1.1.5. Contexts of the science items

PISA 2015 examines the extent to which students are capable of displaying science competencies appropriately within a range of applications (health, natural resources, environment, hazards, frontiers of science and technology) in the following settings:

- Personal – self, family and peer groups
- Community – local/national
- Global – life across the world.

1.1.6. Attitudes towards science

The PISA 2015 framework also views scientifically-literate citizens as individuals who 'have an interest in scientific topics, engage with scientific-related issues, have a concern for issues of technology, resources and the environment, and reflect on the importance of science from a personal and social perspective' (OECD, 2016a, p. 7). A number of questionnaire items (see below) were developed for PISA 2015 to assess students' dispositions towards science. These formed three broad clusters:

- ***Interest in science and technology*** – this cluster includes items that assess students' interest in pursuing careers in science-related areas at age 30

- ***A concern for the environment and an environmentally-sustainable way of life –*** items in this cluster assess understanding of basic principles of ecology, environmental awareness and a responsible disposition towards the environment

- ***Appreciation of, and support for, scientific inquiry*** – items in this cluster look at students' appreciation of, and support for, scientific enquiry, including their use of the scientific method. They also include environmental awareness.

1.1.7. Comparison with the 2006 science framework

As shown in Table 1.1, science literacy was also a major assessment domain in 2006. For that cycle, scientific knowledge comprised two components: knowledge of science and knowledge about science (OECD, 2006). In PISA 2015, knowledge about science is split into two components – Procedural Knowledge and Epistemic Knowledge, though these are combined for scaling purposes. PISA 2006 included the science competencies of explaining phenomena scientifically, identifying scientific issues, and using scientific evidence. In 2015, the three assessed competency clusters are: explaining phenomena scientifically, evaluating and designing scientific enquiry, and interpreting data and evidence scientifically. Hence, for the most part, the competency clusters overlap across PISA cycles.

In PISA 2006, Knowledge of Science items (comprising 53.3% of science items) were further classified according to the subcategories of Physical Systems, Living Systems, Technology Systems and Earth and Space Systems, while Knowledge about Science items (43.7% of items) were not categorised by knowledge system. In PISA 2015, all science items were categorised according to three subsystem categories (the Technology Systems subcategory was dropped), and the three subcategories were collectively labelled content knowledge systems. In 2015, proportionately more items were categorised as Earth and Space Systems, compared with 2006, even after taking into account the absolute increase in the number of classified items.

As in 2015, the PISA 2006 framework included reference to dispositions towards science. In 2006, attitudes were assessed in two ways: through the inclusion of attitudinal items after selected science units in students' test booklets and through items on the Student Questionnaire. In 2015, dispositions towards science were assessed on the Student Questionnaire only.

1.1.8. Science units, item types and distribution of items by framework components

PISA 2015 science comprised two unit or cluster types: standard units, which consist of static materials including text, graphics, tables and graphs and associated questions; and interactive units (simulations), which include interactive stimulus materials and associated questions. A distinction can also be made between 'trend' items, that is, items that were used in earlier cycles of PISA in paper-based format and were transferred to computer for PISA 2015, and 'new' items. The latter include items similar to the 'static' items administered in earlier PISA cycles (although they contain features such as 'drag and drop' and drop-down response options), and the interactive or simulation items. Examples of new science items – both static and interactive – can be found in Appendix B. While some static units and associated items (e.g., Sustainable Fish Farming and Slopeface Investigation) were released after the PISA 2015 Main Study, no interactive items were released so the interactive example in Appendix B (Running in Hot Weather) is drawn from the PISA 2015 Field Trial (administered in 2014).

The item types used in PISA 2015 science are:

- ***Simple multiple choice*** – including selection of a single response from four options, selection of a 'hot spot' within a graphic or text, and selection of an option from a drop-down menu. Simple multiple-choice items are computer-scored.
- ***Complex multiple choice*** – selection of responses to a series of yes/no questions that are treated as a single question; selection of more than one response from a list; completion of a sentence by selecting drop-down choices to fill multiple blanks; and 'drag and drop' responses allowing students to move elements on screen to complete a task of matching, ordering or categorising. Complex multiple-choice items are computer-scored.
- ***Constructed response*** (open response) – which must be coded by humans (written responses ranging from a phrase to a paragraph; a small number of such responses called for a drawing, supported by a simple drawing editor where required). A small number of constructed response items are computer-scored (e.g., where students were asked to 'drag and drop' to indicate the relative size of objects). The others are scored by trained markers.

Table 1.3 shows the distribution of science items by dimensions of the framework. Thus, 48% of the items in the science competency dimension are classified as explain phenomena scientifically, 21% are classified as evaluate and design scientific inquiry, and 30% are described as interpret evidence and data scientifically. These three competencies yield three science competency subscales. When classified by scientific knowledge type, the same pool of 184 items is classified as Content (53%), Procedural (33%) and Epistemic (14%). The relatively small proportion of items in the epistemic knowledge category meant that these had to be combined with Procedural Knowledge items to develop one of the scientific knowledge subscales (the other was content knowledge). When items are classified according to content knowledge systems, one-third (33%) are in the Physical Systems domain, 40% in Living Systems, and the remainder (27%) in Earth and Space Systems. The science items have also been classified by context dimension, with 30% presented in a global context, 59% in a local/national context, and 11% in a personal context. However, unlike the competence, scientific knowledge and content knowledge dimensions, the context dimensions do not yield science subscales.

As shown in Table 1.3, 29% of items are described as simple multiple choice, 36% as complex multiple choice, 32% as open-constructed response – human-coded, and just 3% as open constructed response – computer coded.

Table 1.3. Distribution of PISA 2015 science items by competence, knowledge type, system, context and format – number and percent

	Trend		New		Total	
Science Competences	Number	%	Number	%	Number	%
Explain phenomena scientifically	41	48	48	48	89	48
Evaluate and design scientific enquiry	16	19	23	23	39	21
Interpret evidence and data scientifically	28	33	28	28	56	30
Total	85	100	99	100	184	100
Knowledge Types						
Content	51	60	47	47	98	53
Procedural	24	28	36	36	60	33
Epistemic	10	12	16	16	26	14
Total	85	100	99	100	184	100
Content Knowledge Systems						
Physical	28	33	33	33	61	33
Living	39	46	35	35	74	40
Earth & space	18	21	31	31	49	27
Total	85	100	99	100	184	100
Context						
Global	17	20	38	38	55	30
Local/National	58	68	50	51	108	59
Personal	10	12	11	11	21	11
Total	85	100	99	100	184	100
Format						
Simple multiple choice	29	34	25	25	54	29
Complex multiple choice	25	29	41	41	66	36
Open constructed response: Human coded	28	33	30	30	58	32
Open constructed response: Computer scored	3	4	3	3	6	3
Total	85	100	99	100	184	100

1.2. Framework for Reading Literacy

Reading literacy was a minor assessment domain in PISA 2015, meaning that it was assessed using fewer items than for science, and that performance could not be reported on subscales. The 2015 reading literacy framework is essentially a re-working of the 2009 framework, with slight modifications to take into account the fact that, unlike in 2009 and 2012, digital reading was not assessed. Instead, print reading items were presented on computer in most participating countries. Hence, the framework reflects a reduced role for aspects of digital reading assessed in earlier cycles via the optional computer-based test of digital literacy, and refers to texts used in 2015 as ‘fixed texts’, regardless of the mode in which these are presented. The corollary, ‘dynamic texts’, although referred to in the 2015 framework, were not assessed. Compared with 2012, when reading literacy was also a minor domain, the 2015 assessment includes more items (to increase construct coverage), but fewer students per item, and hence slightly greater uncertainty around scale scores.

1.2.1. Definition of reading literacy

The definition of reading literacy in PISA 2015 (based on the 2009 definition) is as follows:

> Reading literacy is understanding, using, reflecting on and engaging with written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society (OECD, 2016a, p. 49).

Reading literacy is viewed as including a wide range of cognitive competencies, from basic decoding, to knowledge of words, grammar and larger linguistic and textual structures and features, to knowledge about the world. It also includes metacognitive competencies (the awareness of and ability to use a variety of appropriate strategies when processing texts).

Several aspects of reading comprehension are included in or implied by the definition. Importantly, there is provision for basic comprehension (understanding), application (using information) and reflection, which is linked to a personal interaction with the text (drawing on one's own thoughts and experiences when reading a text). In PISA, reflection is viewed as involving both text content, and the form and structure of text.

Reference to engagement in the definition points to motivational aspects of reading. The PISA 2015 reading literacy framework describes this as including 'an interest in and enjoyment of reading, a sense of control over what one reads, involvement in the social dimension of reading, and diverse and frequent reading practices' (OECD, 2016a, p. 50).

The term 'written texts' is intended to include both 'fixed' and 'dynamic' texts, although, as indicated above, understanding of dynamic digital texts was not assessed in PISA 2015.

The PISA assessment framework is based on three major task characteristics: situation (the range of broad contexts or purposes for which reading takes place), text (the range of material that is read), and aspect (the cognitive process that describes how readers engage with a text). All three are deemed important, while text and aspect are viewed as having a direct influence on the difficulty of reading tasks.

As noted earlier, all texts selected for inclusion in PISA 2015 (a subset of texts employed in the PISA 2009 paper-based assessment of reading) have been categorised as fixed, with no dynamic texts included. Texts used in PISA 2015 were also classified according to text format and text type.

1.2.2. Text format

Four text formats are included in PISA 2015 reading literacy:

- ***Continuous texts*** – these comprise sentences organised into paragraphs such as newspaper reports, essays, novels, short stories, reviews and letters. Though not assessed, these include texts on e-book readers (that is, fixed texts presented in electronic format). Discourse markers include paragraphing, different font sizes (including use of font for emphasis), sequence makers (first second, third etc.) and causal connectors (therefore, for this reason, since etc.)

- ***Non-continuous texts*** – these comprise documents, often presented in list format. In addition to simple lists, these include tables, graphs, diagrams, advertisements, catalogues, indexes and forms
- ***Mixed texts*** – these include texts based on a combination of continuous and non-continuous formats (e.g., a prose explanation that includes a graph or table) that often appear in magazines, reference books and reports. In dynamic format, not assessed in PISA 2015, such texts include on-line forms, e-mail messages and forums that combine continuous and non-continuous texts.
- ***Multiple texts*** – these comprise two or more texts that have been generated independently, but are combined for the PISA assessment, albeit loosely linked. Such texts may have a single 'pure' form, or may comprise continuous and non-continuous texts and include multiple texts on the same topic that may contradict one another.

1.2.3. Text aspects or processes

PISA defines aspects as approaches or purposes that readers use to negotiate their way into, around and between texts. Five aspects are identified in the framework: retrieving information, forming a broad understanding, developing an interpretation, reflecting on and evaluating the content of a text, and reflecting on and evaluating the form of a text. Due to the relatively small numbers of items in some categories, these are merged into three broader aspects:

- ***Access and retrieve*** – tasks that require the reader to focus on and extract separate pieces of information in a text to make internal sense of the text. This involves such processes as locating, scanning, and selecting relevant information, which may be located in one or more parts of a text.
- ***Integrate and interpret*** – tasks that require the reader to focus on relationships between sentences and between parts of a text to achieve a broad understanding. Integrating involves establishing the coherence of the text by combining various parts to make meaning, and includes identifying similarities, making comparisons of degree, and establishing cause and effect relationships. Interpreting refers to the process of making meaning from something that is not stated in the text. It involves summarising main ideas, distinguishing between principal and subordinate elements, or finding a specific instance of something described earlier in general terms
- ***Reflect and evaluate*** – tasks that require the reader to reflect on the content and format of texts by drawing on knowledge outside the text (prior knowledge or knowledge from other texts) and relating it to what is being read. Reflecting on content is concerned with the notional substance of a text, while reflecting on form involves reflecting on a text's structure or formal features. In reflecting on and evaluating content, readers may assess claims in the text against their own knowledge of the world, and may have to articulate or defend their own points of view. In reflecting on and evaluating the form of a text, readers may determine the usefulness of a text for a particular purpose, or evaluate the author's use of particular text features to accomplish a goal.

The framework notes that, in practice, the aspects described above are not entirely separate, but are interrelated and interdependent. Moreover, all readers, regardless of their overall proficiency, are expected to demonstrate some competence on each of the aspects.

1.2.4. Reading situations/contexts

PISA identifies four situations in which reading texts are used. These are linked to the contexts and uses for which an author constructs a text:

- ***Personal*** – where the reader draws on texts linked to personal interests. These include personal letters, fiction, biography and informational texts that are intended to be read to satisfy curiosity. Though not assessed in PISA 2015, such texts include personal e-mails, instant messages, social media/networking sites, and diary-style blogs
- ***Public*** – where texts relate to activities and concerns of society more generally. Such texts include official documents and information about public events, as well as forum-style blogs, news websites and public notices that are encountered both online and in print.
- ***Educational*** – where texts are designed for instructional purposes. They include textbooks and interactive learning software. They typically involve reading for information.
- ***Occupational*** – where texts include job advertisements or workplace directions, whether in print or online. Such texts are linked to PISA's efforts to assess students' preparedness for the literacy demands of life after school.

1.2.5. Item types and distribution of items by framework components

Similar to the science assessment framework, PISA 2015 reading included four item types: simple multiple choice (where the student selects from among four possible items), complex multiple choice (where the student responds yes or no to a number of statements), open constructed-response items that are coded by trained coders, and open constructed-response items that are computer-coded. The PISA 2015 reading literacy framework acknowledges that, since PISA 2015 involved the transfer of a paper-based test to a computer-based platform, it was not possible to avail of the full range of item formats that are available on a computer-based platform.

Table 1.4 summarises the components of PISA 2015 reading literacy.

Table 1.4. Distribution of PISA 2015 reading items by aspect, text format, component and item format – number and percent

Component	Number	%	Component	Number	%
Text format			Situation		
Continuous	54	60	Educational	26	30
Non-continuous	24	30	Occupational	16	18
Mixed	7	7	Personal	29	33
Multiple	3	3	Public	17	19
Total	88	100	Total	88	100
Aspect			Item Format		
Access and retrieve	22	25	Simple multiple choice	31	35
Integrate and interpret	46	52	Complex multiple choice	11	13
Reflect and evaluate	20	23	Open response: Human coded	40	45
Total	88	100	Open response: Computer scored	6	7
			Total	88	100

1.3. Framework for Mathematics

Like reading literacy, mathematics was a minor assessment domain in PISA 2015. The 2015 mathematics framework is essentially a re-working of the 2012 framework, when mathematics was a major assessment domain, but it also describes the process of transferring items from paper to computer format. Although a test of computer-based mathematics was administered as part of PISA 2012 (using a completely different set of items from those used in the paper-based test), the PISA 2015 assessment did not use any of the 2012 computer-based items, and instead transferred a subset of PISA 2012 paper-based items to computer.

Compared with earlier PISA cycles in which mathematics was a minor domain, PISA 2015 includes more mathematics items, with a view to increasing construct coverage, though the numbers of students answering each item in PISA 2015 was lower than, for example, in 2006 and 2009. The improved construct coverage, based on the inclusion of a greater number of trend items, is at the expense of somewhat less precise score estimates for 2015.

1.3.1. Definition of mathematical literacy

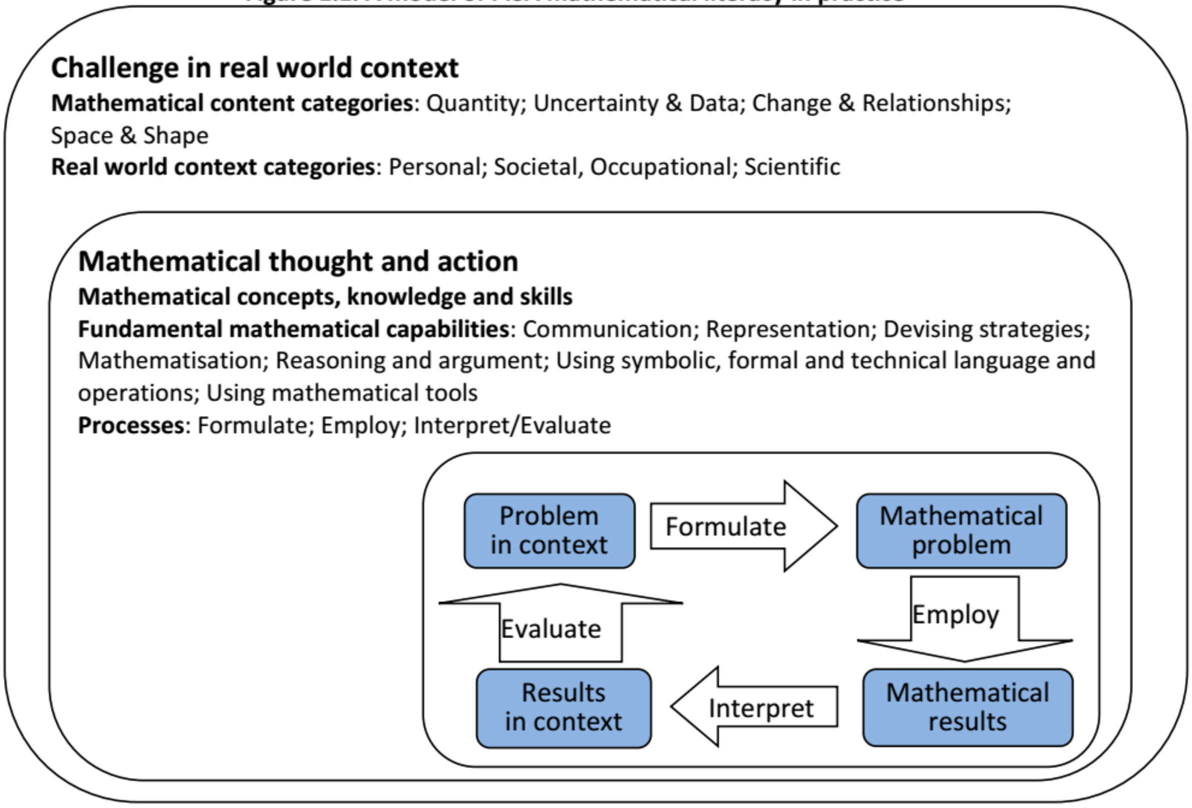
The definition of mathematical literacy in PISA 2015 (based on the 2012 definition) is as follows:

> Mathematical literacy is an individual's capacity to formulate, employ and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematics concepts, procedures, facts and tools, to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens (OECD, 2016a, p. 65).

On the one hand, PISA mathematical literacy supports the importance of students developing a strong understanding of concepts of pure mathematics and the benefits of being engaged in explorations in the abstract world of mathematics. It emphasises the need to develop students' capacity to use mathematics in context, and argues that this is equally important for students at or near the end of their formal mathematics education, as well as those planning to engage in further study of mathematics, as it makes mathematics more relevant for all students and increases their motivation. The framework emphasises that mathematical literacy is an attribute along a continuum, with some individuals being more mathematically literate than others, and with potential for growth always there.

Figure 1.1 provides an overview of the key elements in the definition of mathematical literacy and how these relate to one another. The outer-most box shows that mathematical literacy occurs in the context of a real-life challenge or problem, described in the framework in terms of the context in which it arises, and the content to which it relates (both described below). The middle box shows that a student needs to draw on mathematics concepts, knowledge and skills to formulate situations mathematically, employ mathematical concepts, facts, procedures and reasoning, and interpret, apply and evaluate mathematical outcomes. The inner box portrays the mathematical modelling cycle described in the PISA framework. This is a simplified rendition of the stages involved in solving mathematical problems in contexts. It begins with a problem situated in a meaningful context. The problem solver formulates the problem according to mathematical concepts, in order to make it amenable to mathematical treatment. Following this, the problem solver employs mathematical strategies to obtain mathematical results. The mathematical results are then interpreted and evaluated in terms of the original contextual problem. The extent to which all cycles of the problem solving process are deployed will depend on the nature of the problem to be solved, and some problems may involve only parts of the cycle.

Figure 1.1. A model of PISA mathematical literacy in practice



Adapted from Figure 1.1, OECD (2013), p. 26

1.3.2. Mathematical processes and underlying mathematical capabilities

As indicated in the definition of mathematical literacy and in Figure 1.1, PISA incorporates three key processes in the context of mathematical problem solving: formulating situations mathematically, employing mathematical concepts, facts, procedures and reasoning, and interpreting, applying and evaluating mathematical outcomes.

The framework also identifies seven mathematical abilities that underpin these processes: communication, mathematising, representation, reasoning and argument, devising strategies for solving problems, using symbolic, formal and technical language and operations, and using mathematical tools. Each of these abilities can be displayed at different levels of competence, and together form the basis of the description of proficiency levels used to report performance on mathematics. The three main processes are:

- ***Formulating*** – involves identifying opportunities to apply and use mathematics, and seeing that mathematics can be applied to understand or resolve a particular problem or challenge presented. It includes translating a real-world problem into a form amenable to mathematical treatment, providing mathematical structure and representations, and identifying variables and making simplifying assumptions to help solve the problem or meet the challenge

- ***Employing*** – involves applying mathematical reasoning and using mathematical concepts, procedures, facts and tools to arrive at a mathematical solution. It includes performing calculations, manipulating algebraic expressions and equations or other mathematical models, analysing information in a mathematical manner from mathematical diagrams and graphs, and developing mathematical descriptions and explanations and using mathematical tools to solve problems

- ***Interpreting*** – involves reflecting upon mathematical solutions or results and interpreting them in the context of a problem or challenge. It includes evaluating mathematical solutions or reasoning in relation to the context of the problem and determining whether the results are reasonable and make sense in the situation.

1.3.3. Mathematical content areas

PISA identifies four mathematical content areas – Change and Relationships, Shape and Space, Quantity and Uncertainty and Data. It is argued that these 'meet the requirements of historical development, coverage of the domain of mathematics and the underlying phenomena which motivate its development, and are linked to the major strands of school curricula' (OECD, 2016a, p. 71). Each is described below:

- ***Change and Relationships*** – involves understanding types of change and recognising when these occur in order to use suitable mathematical models to describe and predict change. Mathematically, this involves 'modelling the change and relationships with appropriate functions and equations, as well as creating, interpreting, and translating among symbolic and graphical representations of relationships' (OECD, 2016a, p. 71). Aspects of traditional mathematics content of functions and algebra, including algebraic expressions, equations and inequalities, and tabular and graphic representations are central and must be drawn on to describe, model and interpret change phenomena. Representations of data and relationships described using statistics are also viewed as important, as is a firm grounding in the basics of number and units

- ***Space and Shape*** – involves understanding perspective, creating and reading maps, transforming shapes with and without technology, interpreting views of three-dimensional scenes from various perspectives and constructing representations of shapes. This content area draws on geometry, spatial visualisation, measurement and algebra. Geometry is seen as 'an essential foundation for Space and Shape, but the category extends beyond traditional geometry in content, meaning and method, drawing on elements of other mathematical areas such as spatial visualisation, measurement and algebra' (OECD, 2016a, p. 71)

- ***Quantity*** – involves understanding measurements, counts, magnitudes, units, indicators, relative size, and numerical trends and patterns. Aspects of quantitative reasoning deemed important for mathematical literacy include number sense, multiple representations of numbers, elegance in computation, mental calculation, and estimation and assessment of the reasonableness of results.

- ***Uncertainty and Data*** – includes knowledge of variation in processes, having a sense of the quantification of that variation, acknowledging uncertainty in measurement, and knowing about change. It also involves forming, interpreting and evaluating conclusions drawn in situations where uncertainty is central. The interpretation and presentation of data are viewed by PISA as important elements of uncertainty and data.

The following content is identified by PISA as central to all four mathematical content areas: functions, algebraic expressions, equalities and inequalities, co-ordinate systems, relationships within and among geometrical objects in two and three dimensions, measurement, numbers and units, arithmetic operations, percentages, ratios and proportions, counting principles, estimation, data collection, representation and interpretation, data variability and its description, samples and sampling, and chance and probability.

1.3.4. Mathematical contexts

The ability to engage with mathematical problems in a variety of contexts is central to PISA. The manner in which mathematical thinking is applied to a problem often depends on the setting in which it is encountered. The context is the aspect of the individual's world in which a problem is placed. PISA identifies four context categories: personal, occupational, societal and scientific. The major purpose of context categories is to ensure that the selection of items reflects a broad range of settings that are relevant to 15-year-olds. Items which are intra-mathematical, where all the elements belong to the world of mathematics, fall within the scientific context. The four contexts are defined as follows:

- ***Personal –*** these items focus on activities of one's self, one's family or one's peer group. Such contexts include: food preparation, shopping, games, personal health, personal transportation, sports, travel, personal scheduling, and personal finance
- ***Occupational –*** these are centred on the world of work and include such activities as measuring, costing and ordering materials for building, payroll/accounting, quality control, scheduling/inventory, design/architecture and job-related decision making. These contexts are viewed as relating to any level of the workforce, from unskilled work to the highest levels of professional work, though items in these contexts are designed to be accessible to 15-year-olds
- ***Societal –*** these focus on community (whether local, national or global), and can involve voting systems, public transport, government, public policies, demographics, advertising, national statistics and economics. The focus of these problems is on a community (rather than a personal) perspective
- ***Scientific –*** these relate to the application of mathematics to the natural world and issues and topics related to science and technology. Contexts include weather or climate, ecology, medicine, space science, genetics, measurement, and the world of mathematics itself.

1.3.5. Item types and distribution of mathematics items by framework components

PISA 2015 mathematics included six half-hour units of items drawn from PISA 2012 (albeit on computer rather than on paper) – three more than on previous occasions when mathematics was a minor domain. The inclusion of six units was intended to stabilise and improve the measurement of trend. Item formats used in PISA 2015 mathematics include: open-constructed human-coded, where students are required to supply an extended written response to show the steps taken in solving a problem, or to explain how an answer was reached, with responses scored by trained human coders; open-response computer-coded, where students are invited to provide a short answer and the answer is scored by computer (such as a numerical response to a problem); and selected response items, where students select one or more correct responses from a number of options. Multiple-choice items with one correct response are described as ‘simple’, and those with multiple ‘yes/no’ options as ‘complex’.

Table 1.5 shows the distribution of PISA 2015 mathematics items by process, content area, item format and context.

Table 1.5. Distribution of PISA 2015 mathematics items by process, content area, context and item format – number and percent

Component	Number	%	Component	Number	%
Process			Item Format		
Formulating	21	30	Simple Multiple Choice	16	23
Employing	29	42	Complex Multiple Choice	13	19
Interpreting	19	28	Open Response – Human Coded	18	26
Total	69	100	Open Response – Computer-Coded	22	32
			Total	69	100
Content			Context		
Change & Relationships	16	23	Occupational	13	19
Quantity	18	26	Personal	11	16
Space and Shape	17	25	Scientific	19	28
Uncertainty & Data	18	26	Societal	26	38
Total	69	100	Total	69	100

1.4. Questionnaire Framework

In addition to assessing science, reading literacy and mathematics, PISA collects background information using questionnaires. The information derived from questionnaires is conceptualised at four levels: the student, classroom and school levels, and the level of the educational system as a whole. PISA 2015 included six questionnaires:

- Student Questionnaire (Required)
- School Questionnaire (Required)
- Information and Communication Technology (ICT) Familiarity Questionnaire (Optional)
- Parent Questionnaire (Optional)
- Educational Career Questionnaire (Optional)
- Teacher Questionnaire (Optional)

Ireland administered the first five questionnaires in the PISA 2015 Field Trial (implemented in spring 2014), and the first four in the PISA 2015 Main Study (in spring 2015). Each questionnaire included questions authored by the OECD’s contractors (both new and trend) and a small number of ‘national’ questions (provided by the Educational Research Centre). Questionnaires for students (the Student Questionnaire, the ICT Familiarity Questionnaire, and the Educational Career Questionnaire) and schools (the School Questionnaire) were offered on computer only. Both paper-based and computer-based versions of the Parent Questionnaire were available.

Two further questionnaires were developed by the ERC and administered in the PISA 2015 Main Study in Ireland but not in other participating countries:

- Test-Taking Behaviour Questionnaire
- Science Co-ordinator Questionnaire

The Science Co-ordinator Questionnaire, which asked science co-ordinators about the teaching and learning of science at school level, was available in paper- and computer-based versions, while the

Test-Taking Behaviour Questionnaire, which asked students about their experiences and strategies in taking the PISA tests, was available on paper only.

Following a brief consideration of the overall questionnaire framework for PISA 2015, each questionnaire administered in Ireland is described in more detail. Readers wishing to learn more about the rationale underlying the six OECD questionnaires are referred to OECD (2016a), where items administered across all countries are also shown.

1.4.1. The PISA Questionnaire Framework

The PISA Questionnaire Framework, outlined ahead of PISA 2012 (OECD, 2013) includes four key components:

- ***Non-cognitive outcomes*** – attitudes, beliefs, motivation and aspirations, and learning-related behaviours, such as invested learning time, which are measured via the Student Questionnaire (often with reference to the main assessment domain – science in 2015) and the ICT Familiarity Questionnaire. These outcomes can be viewed as important in explaining variation in achievement, and may also be important in their own right
- ***Student background factors*** – socioeconomic status and immigrant background, as well as variables that contribute to PISA's long-standing measure of economic, social and cultural status (ESCS), an amalgamation of parent occupational status, parent education, and an index of home possessions that includes cultural possessions, family wealth, home educational resources, and number of books in the home. Also included is information on parental support for students' learning (via the optional Parent Questionnaire). PISA also uses aggregated student background variables to characterise school background such as the proportion of immigrant students in a school, or the average socioeconomic status of the school (based on the average of the ESCS scores of students in the school)
- ***Teaching and learning*** – drawing on teacher effectiveness research, PISA gathers data on core factors associated with teaching, learning and school organisation. The data, which are mainly gathered via the School and Student Questionnaires, focus on teacher qualifications, teaching practices, classroom climate, learning time and learning opportunities provided within and outside the school. Data are also gathered on aspects of teaching, including structure and classroom management, teacher support and cognitive challenge. In general, questions about teaching and learning relate to the major assessment domain – science in the case of PISA 2015
- ***School policies and governance*** – drawing on school effectiveness research, PISA gathers data on factors associated with teachers' professional development, leadership and school management, parental involvement, school climate (e.g., high achievement expectations), and use of assessment and evaluation for improvement. Also covered is school-level support for teaching the major assessment domain, such as provision of laboratory space, information and communications technology, and a school curriculum for science education. Data on locus of decision making, and on selection and assessment and evaluation practices at school level are also gathered.

Table 1.6 shows the modular structure of the PISA questionnaire design. Each of the 19 individual modules could be the focus of in-depth thematic analysis. The table also shows clusters of modules that were emphasised across questionnaires in the study. These include modules 1, 2 and 12, which address teaching and learning (mainly in the context of science for PISA 2015), modules 2 and 13-16 which address school policies, and modules 17-19 which address system-level governance. The framework is designed to be applicable to future PISA cycles, notwithstanding changes in the major domain from cycle to cycle. Specific themes that cut across modules include Educational Careers (modules 6, 8 and 9) and ICT (modules 7, 10 and 16). Some modules are not relevant to Ireland in the context of PISA 2015 (e.g., dispositions for collaborative problem solving, since Ireland did not take part in the optional assessment of problem solving).

Table 1.6: Modular structure of the PISA questionnaire design, adapted for 2015 with science as the major domain

<table>
<tr><th></th><th colspan="2">Student and school background</th><th colspan="3">Process</th><th rowspan="2">Non-cognitive outcomes</th></tr>
<tr><th></th><th>Family</th><th>Education</th><th>Actors</th><th>Core processes</th><th>Resource Allocation</th></tr>
<tr><td rowspan="2">Science-related Topics</td><td rowspan="2"></td><td rowspan="2">5. Out-of-school science experience</td><td>1. Teacher qualifications and professional knowledge</td><td>2. Science teaching practices</td><td>12. Learning time and curriculum</td><td rowspan="2">4. Science-related outcomes: motivation, interest, beliefs</td></tr>
<tr><td colspan="3">3. School-level learning environment for science</td></tr>
<tr><td rowspan="2">General Topics</td><td rowspan="2">7. Student SES and family</td><td rowspan="2">9. Educational pathways in early childhood</td><td>14. Parental involvement

15.Leadership and school management</td><td>13 School climate: interpersonal relations, trust, expectations</td><td>16. Resources</td><td>6. Career aspirations

10. General behaviour and attitudes</td></tr>
<tr><td>17. Locus of decision making in school system</td><td>19. Assessment, evaluation and accountability</td><td>18. Allocation, selection and choice.</td><td>11. Dispositions for collaborative problem solving.</td></tr>
</table>

Source: OECD (2016a, Figure 6.2, p. 107). Modules 1, 2, 12 = Teaching and learning cluster. Modules 2, 13, 14, 15, 16 = School policies cluster; Modules 17, 18, 19 = Governance cluster.

The non-cognitive outcomes referred to in module 4 (science-specific) include self-efficacy in science, interest in broad science topics, enjoyment of science (a trend measure), instrumental motivation to learn science (trend), epistemological beliefs, environmental awareness (trend), and environmental attitudes (trend).

Modules 6, 10 and 11 include some non-cognitive outcomes such as test anxiety, well-being in general, well-being at school (sense of belonging) (trend), achievement motivation, perceived ICT competence, and time use (activities before and after school).

Many of the questionnaire outcomes are presented as scales (such as a scale for self-efficacy in science). Each such scale is based on a number of component items that are each responded to individually (often in terms of frequency, or level of agreement), and then scaled using regression (usually to an OECD average of 0 and a standard deviation of 1). Some of the scales (e.g., instrumental motivation and well-being at school or sense of belonging) are trend scales, with components that can be used to track changes over time. Average scores on trend scales and items can be compared with earlier PISA cycles, especially 2006, when science was last a major domain.

It is noteworthy that many of the items under assessing teaching and learning activities (modules 2 and 12) are based on data provided by students rather than teachers. For example, a scale on inquiry-based teaching practices in science is based on nine activities (items) and students are asked to indicate the frequency with which these occur (e.g., 'Students are given opportunities to explain their ideas'). The use of student data as a proxy for teacher data arises from the complexity of the PISA design, where 15-year-olds are selected at random across multiple grade levels, with just a handful of students in any given class being taught by the same teacher. Even with a Teacher Questionnaire (which was optional in PISA 2015), it is often necessary to aggregate teacher data to the school level, thereby weakening associations with achievement and, by implication, inferences that can be made about the effectiveness of teaching strategies.

Parental involvement (module 14) focuses on parents' opinions (e.g., about aspects of science) and their engagement in their child's learning. Although PISA has included a Parent Questionnaire since 2006, 2015 is the first time it has been administered in Ireland. PISA also includes questions relating to parents in the School Questionnaire (e.g., parent-school communication and collaboration), and in the Student Questionnaire (parental support for learning).

1.4.2. Overview of the content of the questionnaires

The PISA Questionnaire Framework is actualised in the questionnaires described below.

School Questionnaire

The PISA School Questionnaire was completed online by school principals when the assessment was administered in schools (March 2015). The international questions address:

- School background information (e.g., school size, class size, numbers of computers available for student use)
- School management (school leadership activities, responsibility of the school for various tasks and policies, school admissions policy, funding sources, factors hindering instruction)
- Teaching staff (numbers of teachers and qualifications, professional development for school staff)
- Assessment and evaluation (assessment methods used in the school, how outcomes of standardised assessments are used, activities to ensure school quality and improvement, use of data from internal and external evaluations)
- Targeted groups (policy on grouping by ability, percentages of students with varying characteristics)
- School climate (extent to which learning is hindered by various factors, school-level activities to promote parental involvement, participation of students in school-related activities).

National questions (asked only in Ireland) on the School Questionnaire deal with availability of science subjects at Leaving Certificate level, frequency with which various forms of bullying occurred, policies and procedures to protect student well-being, additional student-level factors hindering teaching and learning, and school-level interventions intended to improve attendance and punctuality.

Student Questionnaire

The PISA Student Questionnaire was completed online by students immediately after they had completed the cognitive tests (science, reading and mathematics) in March 2015. About 45 minutes was allocated. The international questions on this questionnaire address such topics as:

- The student, his/her family and home (gender, grade level, parental education, home resources for learning, other resources, number of books in the home, language spoken at home, repeating a grade level)

- Student's views about life (educational expectations, career at age 30, pressure to achieve)

- Students' school experiences (student's view of him/herself in relation to other students in the school, teacher support for learning, frequency with which student experienced bullying)
- Students' school schedule and learning time (frequency of classes in test language, mathematics and science, time spent on homework, study or practice, truancy and punctuality, participation in physical education at school and outside of school)
- Science learning in school (science courses attended in current and previous school year; selecting science courses, disciplinary climate in science classes, student and teacher activities and interactions in science classes)
- Students' views about science (familiarity with environmental issues, interest in science in general, interest in specific science topics, science self-efficacy, engagement in science activities).

National questions on the Student Questionnaire address the intention to study science at Leaving Certificate level, factors impacting decisions on the study of science at that level, sources of information on science, technology, engineering and mathematics (STEM) courses and jobs, frequency of reading various materials for enjoyment, and experiences related to bullying.

ICT Familiarity Questionnaire

The ICT Familiarity Questionnaire consists of questions regarding the availability of ICT and the student's use of, and attitudes towards, computers. Students completed this questionnaire on a computer immediately after completing the Student Questionnaire. About ten minutes were allocated to completing it. Specific items include the age at which the student first used a digital device, frequency of internet usage inside and outside of school on a typical weekday, frequency of use of digital devices for various purposes at school and outside of school, confidence in using digital devices, and experience with digital media. Several of the questions were drawn from previous PISA cycles, so that trends could be measured.

Parent Questionnaire

Parents of students selected to participate in PISA 2015 were invited to complete the PISA Questionnaire. The questionnaire was distributed to students by schools in paper format. A cover letter with the questionnaire offered parents the opportunity to complete it online if they wished. Questions on this questionnaire relate to:

- The student's family (frequency with which student engaged in various science-related activities as a 10-year old, frequency with which parent engages in various science-related activities with the student at home, extent of parental support for child's learning)
- The student's school (factors considered in school choice, parents' level of satisfaction with various school-related initiatives, engagement of parents in various school-related activities, parents' interaction with child's school friends and with teachers)
- The student's educational pathway in early childhood (childcare arrangements and child's attendance at pre-school)
- Parents' views on science and the environment (family members in science-related careers; interest in science in general and in specific environmental issues)
- Background information (country of origin of parents and grandparents)

National questions include: impact of crisis events that affected the family in the previous 12 months; financial status of the family and concerns about financial well-being; issues around child's attendance at school; and parents' knowledge of the child being bullied (if relevant), reasons for bullying, and actions taken at school level to deal with it.

Test-taking Behaviour Questionnaire

This short paper-based questionnaire was administered to students in Ireland immediately after they had completed the PISA cognitive assessment, and before they were asked to complete the Student Questionnaire. It includes questions on how students felt before taking the PISA test, how well they concentrated during the test, how easy or difficult they found the test, their interest in the test, the level of effort they expended, and strategies they used if they were unsure of the answer to a multiple-choice item, a constructed response item, or an item that required them to perform an action (such as 'drag and drop'). They were also asked whether they had had sufficient time to take the test, and whether they had ever done a test on computer before they took the PISA test.

Science Co-ordinator Questionnaire

This questionnaire, which was administered in Ireland only, was distributed to science co-ordinators with responsibility for Junior Cycle in participating schools in PISA 2015. The purpose of the questionnaire was to gather data specific to the teaching and learning of science at national level that would complement the data obtained via the international questions on science in the School Questionnaire. Questions focused on the study of science, including: criteria used to assign students to the Higher- or Ordinary-level Junior Certificate science examination; activities at school level to promote the engagement of Junior-cycle students in science and science-related activities; characteristics of science teachers; curriculum and assessment in Junior Certificate science including satisfaction with resources and with elements of the then current Junior Certificate science syllabus; approaches to assessment; use of ICT in science classes; and science courses in Transition year. The questionnaire concluded with a section for open comments on strengths and weaknesses of Junior Cycle science.

1.5. Implementation of PISA 2015 in Ireland

This section describes aspects of the implementation of PISA 2015 in Ireland. It includes the development of test materials and questionnaire items, the PISA 2015 Field Trial, the PISA 2015 Main Study, and the implementation of computer-based testing.

1.5.1. The PISA 2015 Field Trial

Twenty-five schools in Dublin and surrounding counties were selected to take part in a Field Trial in spring 2014 and all agreed to participate. The Field Trial had two main functions: to try out new science items (to be delivered by computer in PISA 2015), and to compare performance across countries on paper-based and computer-based trend items (that is, items that had been administered on paper in earlier PISA cycles and were transferred to computer in preparation for PISA 2015). This comparison was intended to inform the OECD and its contractors on whether trends in science, reading literacy and mathematics could be reported in 2015, following computer-based implementation of PISA, even though the core PISA tests had been implemented on paper only in previous cycles. This would be done by examining how item parameters (especially item difficulty) behaved in the two contexts (see Chapter 3 for outcomes).

In each of the 25 schools, 80 students were selected to participate, and were assigned randomly to one of three groups as follows:

- 30 students were assigned to computer-based assessment (CBA) of trend items in science, reading literacy and mathematics
- 20 students were assigned to paper-based assessment (PBA) of trend items in reading, mathematics and science
- 30 students were assigned to computer-based assessment of new science items.

In most schools, testing was spread over two days, with two sessions on the first day (usually a CBA session and a PBA session), and one on the second day. Twelve members of the inspectorate functioned as lead test administrators for CBA-trend sessions, while eight support test administrators and staff of the Educational Research Centre administered the CBA-new-science and PBA-trend sessions. The test sessions in ten schools were administered on laptops brought to the schools by test administrators, as visits prior to the Field Trial found that the schools' computers did not meet PISA specifications. In almost all of the remaining schools, test administrators had to supplement school laptops with one or more of a set of 10 supplementary laptops they brought with them.

Of the 1997 eligible students selected to take part in the Field Trial, 1503 actually participated, giving a response rate of 75.2%. Parents of the selected students were provided with a questionnaire in paper format and requested to complete it. They could opt to complete the questionnaire online by following a link. The vast majority of parents of students who participated in PISA (91.6%) completed the questionnaire, with about 5% doing so online. The outcomes of the Field Trial provided a basis for selecting test and questionnaire items for the PISA 2015 Main Study. Chapter 3 summarises the outcomes of the mode-effect study, involving the comparison of performance on CBA and PBA trend items (the first and second groups above). However, it should be noted that outcomes are examined at international level only, and not at country level, where sample sizes tended to be too small to draw firm conclusions about the effects on performance of switching from paper to computer.

1.5.2. PISA 2015 Main Study

A representative sample of 169 schools in Ireland was selected to participate in PISA 2015 by Westat, a research company working on behalf of the OECD. In this stage of sampling, school size (large, medium or small, depending on the number of 15-year-olds enrolled) and sector (secondary, vocational, community/comprehensive) were the explicit stratifying variables.[7] Within each explicit stratum, schools were ordered by socioeconomic quartile, based on percent of students in a school with a Junior Certificate examination fee waiver, and percentage of 15-year old female students in the school (the implicit stratifying variables). Schools were selected with probability proportional to size (PPS).

In addition to PISA, the Trends in International Mathematics and Science Study (TIMSS) involving students in Second year, was implemented in Ireland in spring 2015. There was minimal overlap of schools between the two studies as overlap controls had been put in place during sampling and a fully-representative sample of schools was drawn for each study,[8] with the TIMSS sample selected

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[7] There were nine explicit strata in all: large, medium and small secondary, vocational and community/ comprehensive schools.

[8] Across samples, there was considerable overlap between first and second replacement schools, though, in practice, replacement schools were not used.

before the PISA sample. Due to lack of availability of other schools within the same explicit stratum, one school was selected in both samples, and this was allocated to TIMSS.

One of the schools selected to participate in PISA was withdrawn due to a critical incident during the testing window, leaving 167 schools in total.

In the second stage of sampling, up to 42 students aged 15 years (those born in 1999) were selected to participate and were divided into two test sessions of up to 21 students.[9] The students were spread over Second year, Third years, Transition year and Fifth year.

In Ireland, the PISA Main Study was carried out in March 2015.[10] Thirty-two Inspectors and one retired principal acted as lead test administrators, alongside twenty-three support test administrators (retired inspectors and principals). The lead and support test administrators were assigned to one of four 'PISA regions' for administrative purposes. One member of the PISA team in the ERC acted as a co-ordinator for each PISA region.

One of the recommendations from the PISA 2015 Field Trial was to administer the assessment solely on laptops hired and transported to schools for the assessment. After a tendering process, a laptop hire company provided 800 laptops, onto which two versions of the assessment were loaded, an English-only language version and an English-Irish language option[11]. The use of laptops controlled by the ERC meant that it was possible to administer the test and questionnaires from each laptop's hard drive, rather than from a USB stick (as had been the practice in the Field Trial), and this seemed to improve the speed at which students' accessed to the material, especially the questionnaires.

In addition to the test administration personnel, technicians were involved in the administration of PISA 2015 in Ireland. Their role was to support the test sessions and the lead and support test administrators, by transporting and setting up laptops, resolving any technical difficulties students had during the assessment, and, after the assessment, uploading the student results to a secure server.

All test administrators and technical support persons attended a training day, and also received support materials (manuals, video clips) outlining the procedures for testing, the completion of paper work (especially student tracking forms), and the uploading of data to the secure server.

PISA school contacts (usually teachers) were identified in all participating schools by principal teachers, and these liaised with the ERC and with the lead test administrator prior to testing. They were also available during PISA testing to deal with any school-level issues that arose.

In all 167 participating schools, testing took place on a single day, with two test sessions running in parallel. Where possible on the first few days of testing and where deviations from usual test administration occurred (e.g., the location was a hotel rather than a school), an ERC staff member (usually the regional co-ordinator) attended the school to assist with test administration. A PISA Quality Monitor (a retired senior inspector, employed by the PISA consortium) visited a number schools selected by the consortium, and submitted a report to the consortium on the quality of test

[9] Fifteen schools had fewer than 42 15-year-olds enrolled and all such students were selected in such schools.
[10] Most countries carried PISA out in spring 2015. A few, including Australia, New Zealand, the UK and the US carried it out in autumn 2015.
[11] Students in schools with a language option were asked to select either English or Irish for the PISA tests. They were given a language option for the questionnaires also. Students in Irish-medium schools, including those with Irish-medium units, were informed of this option before the test date.

administration, including adherence to assessment procedures outlined in the test administration materials.

In all, 6,792 students were selected to participate in PISA 2015 in Ireland. Of these, 117 were deemed ineligible, because, for example, their dates of birth were outside the testing window or they no longer attended the selected school (Table 1.7). A further 737 were did not participate in testing or were absent on the day on which the test was administered. Of these, 44 were not allowed to take part by their parents. In addition, all selected students in the school affected by the critical incident were deemed absent.

Table 1.7. Unweighted numbers of participating, non-participating/absent, ineligible and excluded students in PISA 2015 sample in Ireland, by gender

	Students Participated	Didn't Participate/ Absent	Ineligible	Excluded
All	5,741	737	117	197
Gender				
Male	2,903	432	58	109
Female	2,833	305	59	88

Source: PISA 2015 Weighting Summary Report for Ireland, issued by Westat in May 2016.

In all, 197 students (unweighted) were excluded from testing at school level (Table 1.8). Students exempted because of limited language proficiency included exchange students from other EU countries who were enrolled in post-primary schools in Ireland for part of the 2014-15 school year and were deemed by their school principal or school contact to have insufficient language skills to attempt the PISA tests.

Table 1.8. Unweighted and weighted numbers of within-school exemptions in Ireland, by category

Category	Functional disability	Intellectual disability/ behavioural or emotional disorder	Limited language proficiency	Specific learning disability (e.g., severe dyslexic difficulties)	Total
Number – unweighted	25	57	55	60	197
Number – weighted	213	526	516	570	1825

Source: OECD (2016b), Annex 1.

The weighted school-level response rate in Ireland was 99.3% (Table 1.9). This exceeded the OECD requirement of 85% participation at school level. The weighted and unweighted student response rate in Ireland was 88.6%. This exceeded the required 80.0%. PISA requires that 50% of students selected to take the PISA assessment (excluding ineligible and exempted students) to attempt both test and questionnaire. If this falls below 50%, the school is considered not to have participated. In Ireland, one school was categorised in this way – the school in which a tragic incident occurred, and in which, technically, all students were absent for PISA. Had it been known before the testing window that the school could not take part, it might have been possible to replace it.

Table 1.9. Weighted numbers of participating schools and students in PISA 2015 sample in Ireland

	Number (unweighted)	Percent (unweighted)	Number (weighted) *	Percent (weighted)
Participating schools	167	98.8	61,023	99.3
Participating (assessed) students	5,741	88.6	59,028	88.6

*Weighted by enrolment. Source: OECD (2016b), Annex A2, Table A2.1. Before and after replacement rates are the same as no replacements were made in Ireland.

Table 1.10 gives the numbers of students at each grade level in Ireland who participated in PISA 2015. The highest participation rate is in Third year (60.6%), followed by Transition year (25.6%).

Table 1.10. Unweighted numbers of students and weighted percentages in Ireland completing the PISA 2015 assessment

Grade Level	Ireland equivalent	Unweighted number of students	Weighted percent
Grade 7	First Year	1	0.0
Grade 8	Second Year	102	1.8
Grade 9	Third Year	3,594	60.6
Grade 10	Transition Year	1,442	26.5
Grade 11	Fifth Year	602	11.1

Source: PISA 2015 Weighting Summary Report for Ireland, issued by Westat in May 2016. These values differ slightly from those in Table 6.4, where a national variable was used.

Table 1.9 provides a comparison of participation rates in Ireland in 2012 and 2015. School response rates were equally high in both years (almost 100%). The greater number of participating schools in 2012 (182) compared with 2015 (167) mainly arose because all 'Project Maths' initial schools were included in the 2012 sample. Also, in 2012, up to 35 15-year-olds in each participating school were selected for PISA. In 2015, this increased to 42 (two groups of 21). The improved within-school exclusion rate in 2015 (3.00%) compared with 2012 (4.47%) may have arisen because of closer liaison between the ERC, test administrators and schools in relation to who should be excluded from testing. There was a small increase in the proportion of male students in 2015, from 50.8% to 51.3%, though adjustments to student weights are designed to address this in the analysis of the data.

The improvement in the student response rate in 2015 may also have arisen because of a lower testing burden in that year (around one-third of students in 2012 completed both morning and afternoon testing sessions; morning-only sessions were run in 2015), as well as the use of make-up sessions in schools where large numbers of students were missing during initial testing, usually because of Transition year or sporting activities (six follow-up sessions were conducted in 2015; none were conducted in 2012).

A particular challenge in organising PISA 2015 in Ireland was accessing Transition year students. These students were often engaged in out-of-school activities such as work experience during part of the PISA testing window. This reduced the number of days on which PISA could be administered during the relatively short testing window (the month of March), and also meant that large numbers of schools had to be accommodated on the same day in the early part of the testing window.

Table 1.11. Comparison of selected response rates in PISA 2012 and PISA 2015 in Ireland

	2012	2015
Unweighted number of participating schools	182 (of 185)	167 (of 169)
Weighted school response rate (%)	99	99
Unweighted number of participating students	5,016	5,741
Weighted student response rate (%)	84.1	88.6
Unweighted number of females participating	2545	2833
Weighted percentages of females participating (%)	49.2	48.7
Unweighted number of males participating	2471	2908
Weighted percentage of males participating (%)	50.8	51.3
Unweighted number of absences (including parent refusals)	749	737
Unweighted number of parent refusals	212	44
Unweighted number of within-school exclusions (exemptions)	271	197
Weighted number of within-school exclusions (exemptions)	2542	1825
Weighted within-school exclusion rate (%)	4.47	3.00

1.6. Scaling of PISA Test Data

This section describes how the PISA tests were scaled and how performance in 2015 was linked back to performance in earlier cycles.

1.6.1. Changes to the design and scaling of the PISA 2015 tests

A key element of PISA involves linking performance scales from cycle to cycle. Thus, for example, scores on PISA science in 2015 are intended to be comparable to science scores in 2006 (when science was a major domain for the first time), 2009 and 2012. Similarly, performance on reading literacy in 2015 can be mapped back to 2000 and subsequent cycles, while performance on mathematics can be mapped back to 2003 and subsequent cycles. While the design of PISA and the scaling of performance from cycle to cycle was broadly similar prior to 2015, a number of significant changes occurred in 2015:

- ***Change in the assessment mode*** – prior to 2015, the main PISA tests were administered to students on paper (along with some experimental computer-based tests, which were administered in some countries only, and were scaled separately to the paper-based tests). The mode-effect study, conducted as part of the PISA 2015 Field Trial (see above), was intended to identify items that performed differently across modes so that relevant adjustments could be made in 2015 (see Chapter 3 for outcomes). In the PISA 2015 Main Study, parameters of trend items deemed to have 'scalar' or 'metric' equivalence (stability) across modes in the Field Trial were set to have the same value for all students in all countries in the calibration sample (see below)
- ***Changes in the assessment design*** – the 2015 design was modified to reduce or eliminate differences in construct coverage for major and minor domains, and to eliminate the distinction between major and minor domain for most test takers. In Ireland and in countries that tested on computer but did not include collaborative problem solving, 46% of students took one hour of science and one hour of reading (with half taking reading first), 46% took one hour of science and one hour of mathematics (with half taking mathematics first) and 8% took an hour of science, a half-hour of reading, and a half-hour of maths (with one-half taking science first, one-quarter taking reading first followed by maths, and one-quarter taking maths first followed by reading).[12] Prior to 2015, most students were required to take items in all three assessment domains in most cycles, and this meant that they took a relatively small number of items in each minor domain, leading to weaker construct coverage. Furthermore, fewer items were used to assess minor domains. Greater construct coverage in the minor domains in 2015 was sought by increasing the numbers of items, relative to previous cycles. Thus, for example, reading literacy, a minor domain in both 2012 and 2015, was assessed in 2012 using 44 trend (link) items, and in 2015 using 88
- ***Changes in the calibration sample*** – prior to 2015, item difficulty was estimated using only the responses of students who took part in the most recent assessment (e.g., 2009 data were used in PISA 2012). In 2009 and 2012, the calibration sample comprised a random sample of 500 students per country/economy. In 2000, 2003 and 2006, only students in OECD countries were used to compute item parameters. In 2015, item parameters were re-estimated using all students in all participating countries/economies for the past four cycles

[12] The administration of tests in two or three domains to individual students is required to generate covariance information.

of PISA. This change was implemented to reduce the uncertainty around estimates of item parameters used in calibration.

- ***Changes to the scaling model*** – earlier cycles of PISA used a one-parameter IRT (Item Response Theory) model (including a partial-credit module) when scaling performance; in 2015, a two-parameter logistic (2PL) item response theory (IRT) model for dichotomous data and a generalized partial-credit model for polytomous data were used. The new model also included constraints for trend items (with one-parameter likelihood functions) so that as many such items as possible from earlier cycles could be retained. Unlike its predecessor, the new hybrid model does not give equal weighting to all items when constructing a score, but assigns optimal weights to tasks based on their capacity to distinguish between high- and low-achieving students (OECD, 2016b).
- ***Changes in the treatment of differential item functioning across countries*** – where items performed differently across countries[13], the calibration in 2015 allowed for a limited number of country-by-cycle-specific item parameters. In previous cycles, items that showed differential item functioning (for example, arising from differences in languages across countries) were dropped from scaling. The adjustment in 2015 is intended to reduce the dependency of country rankings on the selection of items included in the assessment (for a country), and hence improve fairness (OECD, 2016b). In scaling the data for Ireland, 40 unique item parameters were used: 3 for maths, 12 for reading literacy, 13 for trend science items and 13 for new science items. The PISA 2015 Technical Report (in preparation) may clarify why these items required country-specific item parameters, and which other countries had country-specific item parameters on the same items
- ***Changes in the treatment of not-reached items*** – in 2015, not-reached items (unanswered items at the end of a section, such as at the end of the first and second hours of testing) were treated as not administered when estimating proficiency (i.e., in scoring student responses), whereas in previous cycles they were treated as incorrect. A reason for this change was to eliminate the opportunity for countries and test takers to randomly guess answers to multiple-choice items at the end of a test. As in previous PISA cycles, not reached items were treated as not administered when computing item parameters (i.e., during scaling).

The OECD (2016b) acknowledges that improvements to the test design and to scaling in PISA 2015 can be expected to result in reductions in link error (the error associated with a particular set of items being used in a particular cycle)[14] between 2015 and future cycles. However, it is also acknowledges that the changes may reflect an increase in link errors between PISA 2015 and previous cycles, as past cycles followed a different design and used different scaling procedures. Furthermore, the OECD notes that the change in the treatment of not-reached items could result in higher scores than would have been estimated in earlier PISA cycles for countries with many unanswered items.

[13] Country-by-item interactions are identified using group-specific item-fit statistics (e.g., mean deviation, and root-mean-square deviation).

[14] Standard errors for comparisons of performance across time account for the uncertainty in the equating procedure that allows scores in different PISA assessments to be expressed on the same scale. This additional source of uncertainty called link error results in more conservative standard errors (larger than standard errors that were estimated before the introduction of this link error) (OECD, 2016b).

1.6.2. Scaling of PISA 2015 tests

As noted above, item parameters were estimated using student responses from cycles between 2006 and 2015, and involved a calibration sample comprising all students in all participating countries/economies. Proficiency means and standard deviations were computed along with item parameters. Individual estimates of proficiency were computed in a second scoring step that was conducted separately for each participating country or economy. Only data for 2015 were scored. The scaling step resulted in a linked scale, based on the assumption of the invariance (stability) of item functions from cycle to cycle, in which means and standard deviations are directly comparable.

The alignment of scales established during PISA 2015 scaling with existing numerical scales from earlier PISA cycles involved the application of a linear transformation to the results. Intercept and slope parameters for the transformation were developed by linking country/economy means and standard deviations, estimated during scaling, with the corresponding means and standard deviations in the published PISA scales from previous cycles. Thus, for science, the transformation involved linking the OECD average mean score and (within country) standard deviation obtained during calibration to the OECD average country mean score and (within country) standard deviation for 2006, when the OECD mean and standard deviation were set to 500 and 100 respectively. For reading, the relevant reference year was 2009, and for mathematics, it was 2012.

The impact of the revised approach to scaling was examined by the OECD's contractors. This involved rescaling data from earlier PISA cycles using the new approach to scaling implemented in 2015 (i.e., the expansion of the calibration sample, the use of unique (country-level) item parameters, the treatment of not-reached items as not administered). Hence, it was possible to compare mean scores for science (2006-2015, 2012-2015), reading literacy (2009-2015, 2012-2015) and mathematics (2012-2015) using new and old methodologies. In general, correlations between country-level mean scores using both new and old methodologies were strong (exceeding 0.98). This was interpreted as indicating that the new scaling methodology and other changes had minimal effects on the ranking of countries in PISA. Mean scores and score differences for Ireland and a number of selected countries based on the new and old scaling methods are given in Chapter 8.

The scaling of PISA data involved the generation of plausible values – estimates of proficiency for students. The number of plausible values generated for each student was increased from 5 in earlier PISA cycles to 10 in PISA 2015. Plausible values are generated based on items students take across domains, as well as context (mainly student) questionnaire variables. The population model used to generate plausible values also uses covariance information among all cognitive domains and among nearly all questionnaire items, as well as numbers of not-reached items.

Students are also assigned plausible values for domains they are not tested on (for example, students taking science and reading literacy in 2015 also receive plausible values for mathematics). These plausible values are imputed with reference to performance on other domains as well as contextual factors at the school and student levels. There is greater uncertainty (measurement error) around plausible values for domains not taken by a student compared with the domains taken.

A detailed description of the design and scaling of PISA 2015 data can be found in the technical report on PISA 2015 (OECD, in preparation).

1.7. Interpreting the Analyses in this Report

Throughout the remaining chapters in this report, a number of statistical terms are used. These are defined in Inset 1.1 below.

Inset 1.1. How to Interpret the Analyses in this Report

OECD average, EU average and EU total

Throughout the report reference is made to the OECD average. This is the arithmetic mean of all OECD countries that have valid data on the indicator in question (e.g., science performance). The numbers of countries contributing to the OECD average varies according to the context in which it is reported. In Chapter 2, where performance on previous cycles of PISA is reviewed, the OECD average is the published average for the year in which PISA was administered. In Chapters 4-7, which report on PISA 2015 outcomes only, OECD average scores are generally based on the 35 OECD member countries that participated in PISA 2015. In Chapter 8, where performance is compared across PISA cycles (for example, science in 2006, 2012 and 2015), the OECD average represents the number of OECD countries in 2015 that had valid data for the earlier cycles. If a country is omitted from the calculation of the OECD average because of difficulties with the data, this is noted under the relevant tables. The terms 'OECD average' and 'OECD mean' are used interchangeably throughout.

Tables and graphs summarising performance in PISA 2015 (Chapters 4-5) include EU average and EU total scores. EU averages were computed in the same way as OECD average scores or percentages. EU total scores are averages (or percentages) of all students in EU countries in PISA, rather than the average of country means, and were drawn from relevant tables in the PISA 2015 OECD report (OECD, 2016b).

Data sources

For international comparisons, results are generally taken from the OECD reports on PISA 2015 (OECD, 2016b, 2016c) and were verified using a preliminary PISA 2015 international database. National analyses, especially those reported in Chapters 6-7, were conducted by the ERC. A number of national items or demographic variables are included in the analyses in these chapters, and in Chapter 8.

Comparing mean scores

Because PISA assesses samples of students, and students only attempt a subset of PISA items, achievement estimates are prone to uncertainty arising from sampling and measurement error. The precision of these estimates is measured using the standard error, which is an estimate of the degree to which a statistic, such as a country mean, may be expected to vary about the true (but unknown) population mean. Assuming a normal distribution, a 95% confidence interval can be created around a mean using the following formula: *Statistic ± 1.96 standard errors.* The confidence interval is the range in which one would expect the population estimate to fall 95% of the time, if many repeated samples were used. The standard errors associated with mean achievement scores in PISA were computed in a way that takes account of the two-stage, stratified sampling technique used in PISA, with adjustments made to the alpha level for multiple comparisons. The approach used for calculating sampling variances for PISA estimates is known as Fay's Balanced Repeated Replication (BRR), or balanced half-samples, which takes into account the clustered nature of the sample. 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.

Statistical significance

Statistical significance indicates that a difference between estimates has not occurred by chance and would likely occur again if the survey was repeated (i.e., for significance at the 5% level, the observed difference would most likely be observed again 95 times out of 100). In this report, mean scores are sometimes compared for countries or groups of students. When it is noted that such scores differ significantly from one another, the reader can infer that the difference is *statistically* significant. Within tables in this report, statistically significant differences are generally indicated in bold.

Standard deviation

The standard deviation is a measure of the spread of scores for a particular group. The smaller the standard deviation, the less dispersed the scores are. The standard deviation provides a useful way of interpreting the difference in mean scores between groups, since it corresponds to percentages of a normally distributed population (i.e., 68% of students in a population have an achievement score that is within one standard deviation of the mean and 95% have a score that is within two standard deviations of the mean).

Proficiency levels

In PISA, student performance and the level of difficulty of assessment items are placed on a single scale for each domain assessed. This means that each scale can be divided into proficiency levels and the skills and competencies of students within each proficiency level can be described. In 2015, six proficiency levels are described for science and mathematics, and seven for reading literacy. In each domain, Level 2 is considered the basic level of proficiency needed to participate effectively and productively in society and in future learning (OECD, 2016b). Within a level, all students are expected to answer at least half of the items at that level correctly (and fewer than half of the items at a higher level). A student scoring at the bottom of a proficiency level has a .62 probability of answering the easiest items at that level correctly, and a .42 probability of answering the most difficult items correctly. A student scoring at the top of a level has a .62 probability of getting the most difficult items right, and a .78 probability of getting the easiest items right.

Correlations

Correlation coefficients describe the strength of a relationship between two variables (e.g., the relationship between socioeconomic status and reading achievement). However, a correlation does not imply a causal relationship. The value of a correlation can range from -1 to +1. A negative correlation (e.g., -.26) means that as one variable increases, the other decreases; a positive correlation (e.g., .26) means that both either increase or decrease together. Correlations are considered *strong* if $r > \pm .56$, *moderate-to-strong* if in the range $r \pm .41$ to $r \pm .55$*, moderate* if from $r \pm .26$ to $r \pm .40$, *weak-to-moderate* if $r =\pm .11$ to $r \pm .25$, and *weak* if $< r \pm .10$.

Bivariate versus multivariate, multilevel analyses

Results in Chapters 4 to 8 are largely based on bivariate analyses, in that they examine the relationship between two variables, such as mean achievement scores by gender. These analyses are useful for identifying patterns but do not account for mediating variables. Multi-variate and multi-level analysis can provide a more nuanced understanding of individual differences in achievement, since an observed relationship between one variable and achievement may be partly or wholly accounted for by the other. In this report, bivariate analyses are mainly reported on, though some outcomes are reported where the OECD has controlled for the effects of school- and student-level socioeconomic status and other relevant variables.

OECD indices

The OECD has uses a two-parameter IRT model (a generalised partial credit model) to scale clusters of items with more than two response options. These include indices of such as Intrinsic Motivation to learn science, Engagement in Science-related Activities, and ICT Use in School in General. Where the indices are based on trend, scaling involved a concurrent calibration of 2006 and 2015 data. Where the index was new, it was scaled to a mean of 0 and a standard deviation of 1, though some scales vary slightly from this, as the late inclusion of Latvia as an OECD country meant that OECD country average scores had to be recomputed. Where indices are reported, percentages are generated for component items (which may be reported in an appendix table), and mean scores and standard errors are presented in the report.

1.8. Summary and Conclusion

The Programme for International Student Assessment (PISA) is a project of the Organisation for Economic Cooperation and Development (OECD), of which Ireland is a member. PISA, which has taken place every three years since 2000, assesses students' preparedness to meet the challenges they may encounter in their future lives, including their participation in education (OECD, 2016a). In 2015, over 500,000 15-year-olds in 74 countries/economies, took part in PISA, including all 35 OECD countries. The major assessment domain in PISA 2015 was science, while reading literacy and mathematics were designated as minor domains. Subscale scores are available for science, but not for reading literacy or mathematics. An optional assessment of collaborative problem solving was also offered in 2015, but Ireland did not take part.

In earlier assessment cycles, PISA was administered as a paper-based test in all participating countries, although some computer-based testing was conducted on an experimental basis. In 2015, most participating countries, including all OECD-member countries, administered the main tests (and questionnaires) on computer. As part of the PISA 2015 PISA Field Trial (administered in 2014), a study was undertaken by the OECD and its contractors to examine whether performance differed in paper-based and computer contexts, and adjustments were made to the 2015 assessment based on the outcomes (see Chapter 3). The mode-effect study used pooled data across countries, and hence did not identify items that might be problematic at individual country level.

The test and questionnaire frameworks for PISA 2015 illustrate the range of competencies and attitudes that were included in the assessment. The science framework has changed in a significant way since 2006, with both knowledge of science and knowledge about science items (the latter now labelled Procedural and Epistemic Knowledge) further categorised according to knowledge subsystems (in 2006, only knowledge of science items were further categorised in this way). Furthermore, the technology systems category was dropped in 2015, resulting in an increased proportion of items in the Earth and Space science category (even after accounting for proportionate increases because of the classification of all items according to the knowledge system they represent). In PISA 2006, dispositions towards science were assessed after selected science unit in students' test booklets, as well as on the Student Questionnaire. In 2015, dispositions were assessed only on the Student Questionnaire. Ireland administered PISA's optional Parent Questionnaire for the first time in 2015. A Test-taking Behaviour Questionnaire administered in 2015 in Ireland only, immediately after students completed the cognitive tests, included questions about students' previous experience with computer-based tests.

The international questionnaire framework for 2015 provides a coherent way of thinking about aspects of students' backgrounds and school environments that might impact on their performance. These include school governance, school policies (including selection of students), teaching and learning experiences, non-cognitive outcomes of schooling (such as attitudes and dispositions), and out-of-school learning experiences.

The administration of PISA 2015 in Ireland involved bringing portable laptops to all participating schools, arranging two simultaneous test sessions, and uploading students' response and questionnaire data to a secure server immediately after testing. Despite the increased challenge, student response rates were higher than in 2012 (and earlier cycles), and fewer students in Ireland were exempted from testing. There was a small increase in the proportion of male students in 2015, from 50.8% to 51.3%, though adjustments to student weights are designed to address any differences between sample and population characteristics.

In addition to the change in assessment mode in PISA 2015, significant changes were introduced into the test design and scaling of student performance. Changes to the test design involved increases in the proportions of items assessed in the minor domains (reading literacy and mathematics), and in the proportions of students completed one hour of reading literacy or mathematics (the minor domains), compared with earlier cycles. These changes were intended to improve construct coverage, as well as provide a more coherent experience for test takers.

The changes to scaling in 2015 involved changes to the calibration sample (which now comprises all students in all participating countries/economies in the past four cycles rather than a random sample of 500 per OECD country based on the previous cycle, as occurred in earlier PISA cycles), the use of a hybrid two-parameter model than can accommodate one-parameter item functions from earlier PISA cycles (compared to a one-parameter Rasch model in earlier cycles), the introduction of cycle-by-country-specific item parameters for items showing differential item functioning (such items were dropped at country-level in the past), and the treatment of not reached items as not administered when scoring students' responses (these were treated as incorrect in the past). According to the OECD (2016b), the impact of these changes on countries' performance was minimal, and within the bounds of measurement error. Chapter 8 includes a comparison of mean score for Ireland and selected countries for earlier PISA cycles, as published in earlier PISA reports, and mean scores for those earlier cycles re-computed using 2015 scaling methods.

It can be concluded that the interpretation of country mean scores in PISA 2015, and changes in performance compared with earlier PISA cycles, are affected by a combination factors, including changes to the PISA framework (mainly confined to science), the transition to computer-based testing, changes in the test design, changes in the calibration sample, changes in the scaling model, changes in the treatment of items that function differentially across countries, and changes in the treatment of not-reached items during scoring. While some of these changes may well improve the accuracy of scores in future PISA cycles, they complicate the interpretation of scores in PISA 2015.

Chapter 2: Performance, Research and Policy Contexts of PISA 2015 in Ireland

The purpose of this chapter is to provide a broad background to support readers in understanding performance and factors associated with performance on PISA 2015 in Ireland. The chapter is divided into three main sections: achievement outcomes of earlier international studies involving Ireland, including PISA; variables associated with science performance in earlier PISA cycles, with particular reference to 2006; and recent developments in education in Ireland that are relevant to PISA 2015.

2.1. Performance in Earlier PISA Cycles and in Other International Studies

Ireland has participated in PISA since 2000. Here, overall performance on each PISA assessment domain between 2000 and 2012 is considered. Performance on subscales is also described for the last cycle in which each domain enjoyed major status (2006 for science, 2009 for reading literacy, and 2012 for mathematics). The data for science in the section below refer to paper-based assessment only, while the data for reading literacy and mathematics refer to paper-based and, where available, computer-based assessment. Other international assessments include TIMSS 1995 and PIAAC 2012.

2.1.1. PISA science

Ireland has performed above the average of participating OECD countries on science in each PISA cycle to date. In the first two cycles (2000 and 2003), when science had the status of a minor assessment domain, Ireland achieved mean scores of 513.4 and 505.4 respectively. The corresponding OECD averages[15] were 500.0 and 499.6 points. Ireland's mean scores were well below the highest performing country in each cycle – Korea (552.1) in 2000 and Finland (548.2 in 2003) (Figure 2.1).

In 2006, students in Ireland achieved a mean score (508.3) that was significantly above the OECD average of 500.0 (Figure 2.1). Finland was again the highest-performing country (563.3), well ahead of the second-highest performer, Hong Kong-China (542.2). In the same cycle (when information on PISA science subscales was last available), students in Ireland performed relatively better on the Identifying Scientific Issues competency subscale (mean score = 515.9) compared with Explaining Phenomena Scientifically (505.5) and Using Scientific Evidence (505.9). The mean scores of students in Ireland were significantly higher than the corresponding OECD averages on Identifying Scientific Issues (OECD average = 500.4), and Using Scientific Evidence (499.2), but not on Explaining Phenomena Scientifically (500.4)[16]. Students in Ireland also performed a little better on the

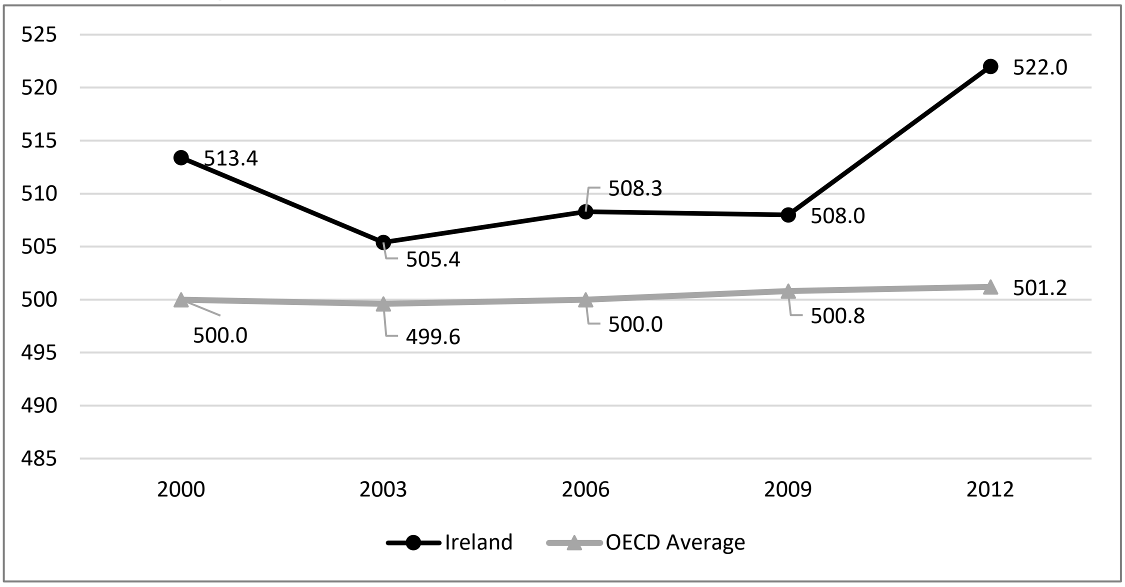
[15] OECD averages reported in this chapter are published averages for the years in question. In Chapter 8, where performance in 2015 is compared with earlier cycles, adjusted OECD averages that take into account the number of OECD countries in each comparison are reported (e.g., OECD countries taking science in 2012 and 2015). This results in small differences from the averages reported in this chapter.

[16] It should be noted that, in PISA 2015, somewhat different sets of science subscales were constructed compared with PISA 2006; hence, only limited comparisons can be drawn between performances on science subscales across the two cycles.

Knowledge *about* Science subscale (512.7) than on the three Knowledge *of* Science subscales (Earth and Space Systems – 508.1, Living Systems – 505.6, Physical Systems – 504.5). Ireland had significantly higher mean scores than the corresponding OECD averages on Knowledge *about* Science and Earth and Space Systems, and mean scores that were not significantly different from the corresponding OECD averages on Living Systems and Physical Systems.

In PISA 2009, students in Ireland achieved a mean score of 508 on science – again above the average for OECD countries (500.8). It is noteworthy that average performance on PISA 2009 science in Ireland was not significantly different from 2006, despite significant declines between 2006 and 2009 in both reading literacy and mathematics. In PISA 2012, when science was again a minor assessment domain, students in Ireland achieved a mean score of 522.0, compared with an OECD average of 501.2. In 2012, the highest-performing PISA participant on science was Shanghai-China (580.1), followed by Hong Kong-China (554.9). Ireland's mean score in 2012 was significantly higher than in all previous PISA assessments.

Figure 2.1. Performance on paper-based Science: PISA 2000 – 2012



PISA science assessments are comparable from 2006 onwards.

PISA also provides data on the proportions of students who perform well on science (those scoring at Proficiency Level 5 or 6 on the PISA overall science scale) and the proportions who perform poorly (those performing below Level 2). In PISA 2006, when science was a major domain, 9.4% in Ireland performed at Levels 5-6, about the same as the OECD average of 9.0%, while 15.5% performed below Level 2, compared with an OECD average of 19.3%. In PISA 2009, 8.7% in Ireland performed at Levels 5-6, compared with an OECD average of 8.5%, while 15.1% performed below Level 2, again fewer than the OECD average of 18.0%. In 2012, 10.8% in Ireland, and 8.4% on average across OECD countries performed at Levels 5-6, while 11.1% in Ireland, and 17.8% on average across OECD countries performed below Level 2. Hence, across cycles, about the same percentages of students in Ireland and on average across OECD countries performed at Levels 5-6 (PISA 2012 was an exception), while fewer students in Ireland than on average across OECD countries performed below Level 2.

In PISA 2006, female students in Ireland had a marginally higher, but not significantly different, mean score (508.5) on overall science than male students (508.1), while on average across OECD countries, males had a significantly higher mean score than females (501.1 and 498.9 respectively). In 2009, female students in Ireland again had a marginally higher mean score than males (509.4 compared with 506.6). On average across OECD countries, males (500.9) and females (500.8) also performed at about the same level. In 2012, male students in Ireland had a mean score (523.9) that was not significantly different from that of females (520.0), while, on average across OECD countries, the mean score for males (501.8) was significantly higher than that of females (500.5).

In general, roughly equivalent percentages of male and female students in Ireland and on average across OECD countries are represented at the lowest and highest proficiency levels on PISA science. However, in 2012, fewer males (11.6%) and females (10.6%) performed below Level 2 than on average across OECD countries (18.6% and 16.9% respectively), while more males (11.7%) and females (9.7%) in Ireland performed at or above Level 5, compared with OECD averages of 9.3% and 7.4% respectively.

In 2006, when there was no overall gender difference in Ireland, there were significant differences in favour of female students on Identifying Scientific Issues subscale (24.6 points), and on Knowledge about Science (9.0 points), while there were significant differences in favour of males on Explaining Phenomena Scientifically (9.3 points), Knowledge of Earth and Space Systems (14.0 points) and Knowledge of Physical Systems (22.8 points). A similar pattern held on average across OECD countries, though males were significantly ahead on Overall Science and on Knowledge of Science subsystems, while females were ahead on Use of Scientific Evidence.

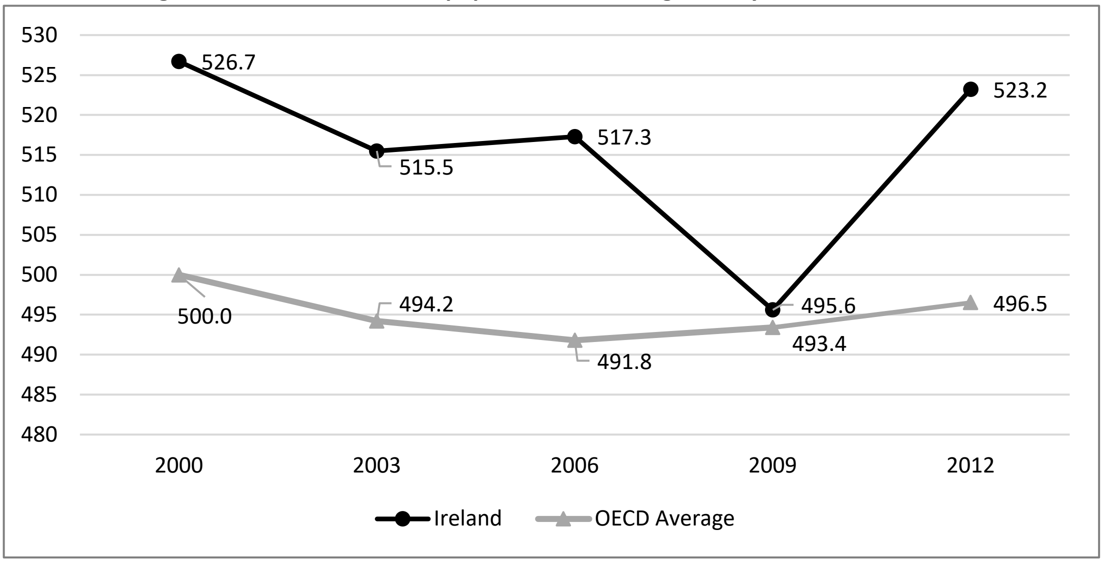
Ireland took part in the PISA 2006 Field Trial of computer-based science, but did not take part in the optional Main Study version in 2006. Outcomes of both are summarised in Chapter 3.

2.1.2 PISA reading literacy

Reading literacy was a major assessment domain in two PISA cycles to date: 2000 and 2009. It was administered on paper to participating countries in all cycles from 2000 to 2015, and on computer, on an optional basis, in 2009 and 2012, when subsets of countries, including Ireland, took part. First, performance on the paper-based tests is described, followed by a brief description of performance on computer-based reading.

In 2000, students in Ireland achieved a mean score (526.7) on PISA reading literacy that was significantly above the corresponding OECD average. Only Finland (546.5) had a significantly higher mean score, though Singapore and Shanghai-China did not participate. In 2003, Ireland’s mean score dropped by 11 score points to 515.5. Although the drop was deemed to be statistically significant at the time, it was later considered to be non-significant, using revised statistical techniques (OECD, 2007). In 2003, the highest-performing countries on reading literacy were Finland (543.5) and Korea (534.1).

Figure 2.1. Performance on paper-based reading literacy: PISA 2000 – 2012



PISA reading assessments are comparable from 2000 onwards.

In 2006, Ireland's mean score on reading literacy was 517.3, which was again significantly above the OECD average of 491.8. The highest-performing country was Korea (556.3), followed by Finland (546.9). In 2009, Ireland's mean score fell to 495.6, which was not significantly different from the OECD average of 493.4, and represented a significant decline in performance in Ireland relative to earlier cycles. The highest-performing country/economy in 2009 was Shanghai-China (555.8), and the highest-performing OECD country was again Korea (539.3), followed closely by Finland (535.9). In 2012, Ireland achieved a mean score of 523.2. This was once again significantly higher than the corresponding OECD average (496.5). The highest-performing country/economy was again Shanghai-China (569.6), and the highest-performing OECD countries were Japan (538.1) and Korea (535.8). Finland slipped to 524.0 points, which was not significantly different from Ireland.

In both 2000 and 2009, data were also available on performance by reading subscale. In 2000, students in Ireland achieved mean scores of 524.3 on the Retrieve subscale, 526.5 on the Interpret subscale, and 533.2 on the Reflect/Evaluate subscale. All were significantly higher than the corresponding OECD averages. Just one country, Canada, performed significantly higher than Ireland on the Reflect/Evaluate subscale. In 2009, when overall performance was significantly lower than in 2000, students in Ireland achieved mean scores of 498.1 on Access and Retrieve, 493.8 on Integrate and Interpret, and 502.5 on Reflect and Evaluate. For all three scales, students in Ireland achieved scores that were not significantly different from the corresponding OECD average scores. PISA has also reported on performance by text type. In 2000, students in Ireland achieved mean scores of 528 and 530 respectively on the Continuous and Non-Continuous Text subscales[17]. On average across OECD countries, the corresponding mean scores were lower, and the difference between them was also small (500, 501 respectively). In 2009, students in Ireland achieved a mean score of 496.6 on Continuous texts and 496.3 on Non-Continuous texts, reflecting lower overall performance. The mean scores for Ireland were not significantly different from their respective OECD averages – 493.8 on Continuous texts and 493.0 on Non-Continuous Texts.

[17] Kirsch et al. (2002) reported rounded mean scores on the PISA 2000 Continuous and Non-continuous Text subscales.

In Ireland, the proportion of students performing below Proficiency Level 2 (the level regarded as the minimum needed to meet the literacy tasks of future work and study)[18], has hovered between 10% and 12% in most cycles except 2009 when it was 17.2%. Also, with the exception of 2009, Ireland has had fewer students performing below Level 2 than on average across OECD countries. A broadly similar pattern emerges where higher-performing students (those scoring at Level 5 or above) are concerned. In Ireland, the proportion performing at Level 5 or higher has ranged from 7.0% in 2009 to 14.2% in 2000. Again, there were more higher achievers in Ireland than on average across OECD countries in each cycle, except in 2009, when 7.4% on average across OECD countries performed at Level 5 or higher (about the same proportion as in Ireland).

In all PISA cycles between 2000 and 2012, female students in Ireland and on average across OECD countries significantly outperformed male students. The difference in favour of females on overall reading literacy in Ireland were 28.7 score points in 2000, 29.0 in 2009, 33.8 in 2006, 39.1 in 2009, and 28.5 in 2012. In all cycles to date, differences in Ireland were smaller than on average across OECD countries, except in 2009 when the OECD average difference was 39.1. In line with their higher mean scores, fewer female than male students in Ireland have performed below Proficiency Level 2. In 2012, for example, 6.1% of females and 13.0% of males in Ireland, performed below Level 2, while on average across OECD countries 11.9% of females and 23.9% of males did so. In addition, more females than males performed at the highest proficiency levels in reading (Levels 5-6) across PISA cycles. In 2012, 14.4% of females and 8.5% of males in Ireland performed at Levels 5-6, while on average across OECD countries 10.8% of females and 6.2% of males performed at these levels.

In PISA 2009 and PISA 2012, students in Ireland participated in an optional test of computer-based reading (digital) literacy, along with subsamples of OECD and partner countries. Unlike the computer-based test of reading literacy that formed a part of PISA 2015, the 2009 and 2012 tests of digital literacy asked students to search websites for information (within a restricted web environment), link information across multiple sites and multiple texts, and communicate some responses in the form of emails. In 2009, 16 OECD countries and three partner countries took part in the assessment of digital literacy. Students in Ireland achieved a mean score of 508.9 on digital literacy, which was significantly higher than the OECD average (498.9), and about the same as Iceland (511.8), Sweden (510.3) and Belgium (507.4). The highest performers were Korea (567.6) and New Zealand (537.4). In PISA 2012, when 23 OECD countries including Ireland, and 9 additional countries, took part in digital literacy, students in Ireland achieved a mean score of 520.1, which was significantly above the OECD average (496.7), and not significantly different from Estonia (522.8) or Australia (520.6). The highest performers were Singapore (567.0), Korea (555.1) and Hong-Kong China (549.8). In 2009, the score-point difference in Ireland in favour of females was 31.1 points, while in 2012, it was 25.3 points. Corresponding OECD averages were 24.5 and 26.0 points respectively. Hence, students in Ireland performed relatively better on digital reading than on print reading in 2009, and at about the same level on both print and digital reading in 2012. Moreover, while females in Ireland performed well ahead of their male counterparts in both years, as was the case on average across OECD countries, the gender difference in Ireland was narrower for digital reading than for print reading in 2012.

[18] In 2009, PISA added new proficiency levels in reading literacy – Levels 1a and 1b instead of the old Level 1, and Levels 5 and 6 instead of Level 5. However, cut-off points for below Level 2 and Level 5 or above remained unchanged.

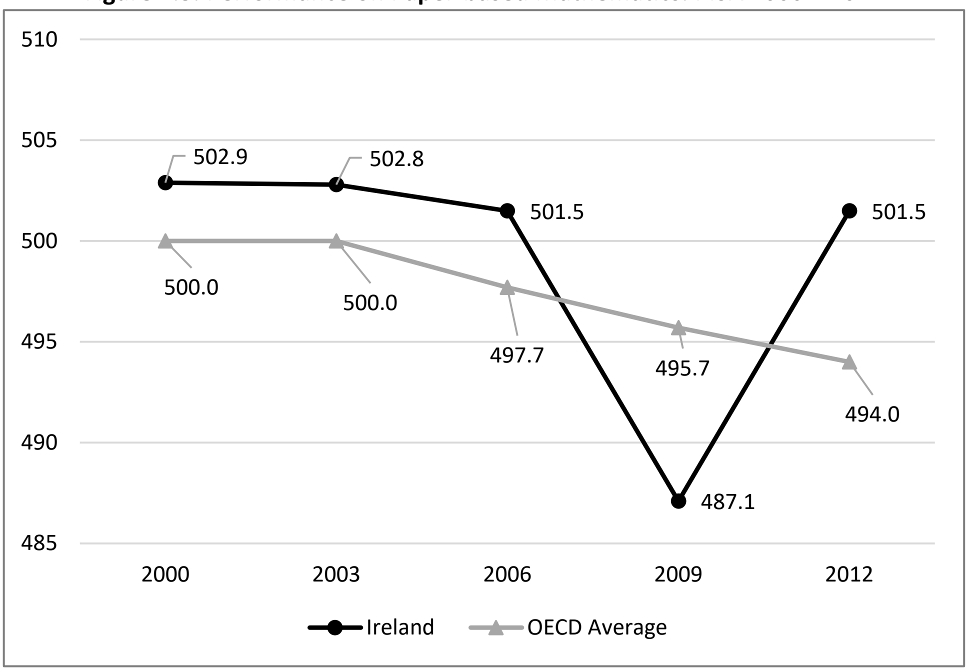
2.1.3. PISA mathematical literacy

Mathematics was assessed as a major domain in PISA in both 2003 and 2012. Further, an optional computer-based test of mathematics in which Ireland participated was offered as part of PISA 2012. Performance on paper-based mathematics is described first, followed by performance on computer-based mathematics.

In 2003, when mathematics was a major assessment domain in PISA for the first time, students in Ireland achieved a mean score of 502.9, which was not significantly different from the OECD average of 500.0 (Figure 2.3). A number of countries, including Hong-Kong China (550.4), Finland (544.3), and Korea (542.2), had mean scores that were significantly higher than Ireland's. In PISA 2006, Ireland's mean score (501.5) was again not significant from the OECD average (497.7) In PISA 2009, the year in which performance on reading literacy in Ireland also dropped, Ireland had a mean score in mathematics (487.1) that was significantly below the OECD average (495.7). In that year, Shanghai-China had the highest mean score (600.1), followed by Singapore (562.0) and Hong-Kong China (554.5). In 2012, Ireland's mean score was 501.5 again, but this time it was significantly above the OECD average (494.0). This seems to have arisen mainly because the OECD average fell back compared with earlier cycles. The highest-performing countries/economies on PISA 2012 mathematics were again Shanghai-China (612.7), Singapore (573.5) and Hong-Kong China (561.2).

Data on performance by mathematics content area are available for PISA 2003 and PISA 2012. In 2003, students in Ireland had mean scores that were above the corresponding OECD averages on Change and Relationships and Uncertainty and Data, not significantly different from the OECD average on Quantity, and significantly below it on Space and Shape. In 2012, mean performance was significantly above the OECD average on Change and Relationships, Uncertainty and Data, and Quantity and significantly below the OECD average again on Space and Shape. Although performance was highest on the Uncertainty and Data subscale in both cycles, students in Ireland performed significantly less well on this subscale in 2012 than in 2003 (508.7 versus 517.2). Space and Shape stands out as a particular are of weakness in both 2003 and 2012.

Figure 2.3. Performance on Paper-based Mathematics: PISA 2000 – 2012



Performance on PISA mathematics assessments can be compared from 2003 onwards.

In PISA 2012, PISA also reported on performance by mathematics process subscale (see Chapter 1 for definitions of processes). Students in Ireland had significantly higher mean scores compared with the corresponding OECD average scores on two subscales: Interpreting, Applying and Evaluating Outcomes; and Employing Mathematical Concepts, Facts, Procedures and Reasoning. Performance was not significantly different from the OECD average on Formulating Situations Mathematically subscale (a process in which students engage *before* they solve a mathematics problem).

In general, fewer students in Ireland than on average across OECD countries have performed below Level 2 proficiency on overall mathematics. In PISA 2003 in Ireland, 16.8% of students performed below Level 2, compared with an OECD average of 21.4%. In 2006, the corresponding estimates were 16.4% and 21.3% respectively, while in 2012, they were 16.9% and 23.0%. In 2009, when overall performance in Ireland was significantly below the OECD average, 20.9% in Ireland, compared with 22.0% on average across OECD countries performed below Level 2.

In 2003, 11.3% in Ireland, and 16.6% on average across OECD countries performed at Level 5 or above. In 2006, the corresponding estimates were 10.2% and 13.3% respectively, while in 2012, they were 10.7% and 12.6%. In 2009, the gap between Ireland (6.7%) and the OECD average (12.7%) was greatest. High-performing countries in PISA tend to have higher proportions of students performing at Level 5 or above. For example, in 2012, 30.9% in Korea, 17.5% in Germany and 15.2% in Finland performed at Level 5 and above.

In PISA 2003 in Ireland, male students (510.2) significantly outperformed female students (495.4). The difference, 14.8 score points, was statistically significant. The OECD average difference, 10.8 score points in favour of males, was also significant. In Finland, there was a non-significant 2.8 score points difference in favour of females. In 2006, there were also significant differences in favour of males in Ireland (11.5 score points) and on average across OECD countries (11.2 points). In 2009, there was a non-significant difference of 7.5 score points in favour males in Ireland, and a significant 11.5 points difference in favour of males on average across OECD countries. In 2012, there was a 15.3 points difference in favour of males in Ireland, and a 10.7 points difference on average across OECD countries. Hence, in most PISA cycles except 2009, male students in Ireland significantly outperformed their female counterparts. In general, gender differences in favour of males in Ireland were greater on Space and Shape (24.7 points in favour of males in both 2003 and 2012), compared with other mathematics content areas.

As part of PISA 2012, students in Ireland participated in an optional assessment of computer-based mathematics, along with students in 22 other OECD countries, and 8 partner countries/ economies. Some of the 41 computer-based items that were administered asked students to sort information and plan efficient sorting strategies, use virtual instruments such as on-screen rulers and protractors, and transform images using a dialog box or mouse to rotate, reflect or translate an image (OECD, 2013). Students in Ireland achieved a mean score of 493.1, which did not differ significantly from the corresponding OECD average of 497.1. Singapore (566.0), Shanghai-China (562.3) and Korea (552.6) were the three highest performers. Interestingly, while students in Ireland did less well on computer-based mathematics, compared with paper-based mathematics in 2012 (-8.4 points), students in a number of countries did better on computer-based mathematics, including the United States (+16.7), France (+13.1) and Norway (+8.2). On average across OECD countries, students had a stronger performance on computer-based mathematics, by 3.1 score points. In Ireland, 17.9% of students performed below Level 2 on computer-based mathematics, compared with 20.0% on average across OECD countries, while 7.0% performed at Level 5 or above, compared with an OECD average of 11.3%. Male students in Ireland achieved a mean score that was 18.6 points higher than females on computer-based mathematics, a difference that was statistically significant. The average difference across OECD countries, 12.5 score points, was also statistically significant.

2.1.4. PISA problem solving

Ireland participated in two assessments of problem solving offered by the OECD – a paper-based measure of cross-curricular problem solving in 2003, and a computer-based measure of 'creative' problem solving in 2012.

The 2003 assessment included real-life problems that involved decision-making, systems analysis and design and trouble-shooting. One unit involved analysing the system for borrowing books in a library, while another involved opening and closing slots to control the flow of water in an irrigation system (see Cosgrove et al., 2005 for sample items). Twenty-nine OECD countries including Ireland and 11 partner countries/economies participated. Students in Ireland achieved a mean score (498.5), which was not significantly different from the OECD average of 500.0. Korea (550.4), Hong-Kong China (547.9) and Finland (547.6) were the highest-performing countries. In Ireland, 12.5% of students achieved at the lowest proficiency level (below Level 1 in this case) compared with an OECD average of 17.3%. The situation was reversed among higher-performers, with 12.3% in Ireland and 18.2% on average across OECD countries achieving the highest level (Level 3)[19]. The mean score for male students in Ireland was just 0.5 score points higher than that of females, and was not statistically significant. The OECD average difference in favour of males, 1.7 points, was not significant either.

The 2012 computer-based assessment of creative problem solving specifically excluded problems requiring expert knowledge of substantive content areas for their solution, and instead took the view that solving many novel, real-life problems requires interacting with a new system in order to discover and apply rules, rather than simply applying prior knowledge. It was intended that the assessment would tap into general cognitive capacities thought to underlie problem solving capacity. These were identified as exploring and understanding, representing and formulating, planning and executing and monitoring and reflecting. Units included operating a climate control unit, working a ticket dispenser, operating a traffic system to minimise travel time, and operating a robot cleaner. The assessment was administered to students in 48 countries/economies, of which 28, including Ireland, were OECD member countries. Ireland's mean score (498.3) was not significantly different from the OECD average of 500.1. High performers included Singapore (562.4), Korea (561.1) and Japan (552.2). Similar percentages of students in Ireland (20.3%) and on average across OECD countries (21.4%) performed below Level 2 on the problem solving proficiency scale, while 9.4% in Ireland and 11.4% on average across OECD countries performed at Level 5 or above. Male students in Ireland had a mean score that was five score points higher than females, but the difference was not statistically significant. On average across OECD countries, there was a significant difference of 6.6 points in favour of male students. A notable feature of both the 2003 and 2012 assessments of problem solving are the relatively strong correlations with other PISA domains. There is some evidence to support the view that the skills assessed in PISA 2012 problem solving are somewhat different from those assessed in other PISA domains. In that year, the correlations between problem solving and print mathematics (0.80), print reading literacy (0.79) and science (0.79) in Ireland were all weaker than the corresponding correlations in 2003 (0.90, 0.87 and 0.85 respectively).

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[19] There were just three proficiency levels on PISA 2003 problem solving.

2.1.5. TIMSS 1995

Students in Second year in Ireland have participated in two rounds of the Trends in International Mathematics and Science Study (TIMSS) – in 1995 and 2015. While PISA's sample is aged based (15-year-olds), TIMSS is grade-based. PISA has a three-year cycle, while TIMSS has a four-year cycle. PISA is concerned with measuring outcomes of schooling, defined as students' ability to apply their knowledge and skills to real-life problems. In contrast, TIMSS is curriculum-based, focusing on content and processes covered in school curricula across participating countries. PISA has one major domain and several minor domains in each cycle, while TIMSS places equal emphasis on mathematics and science in each of its cycles. PISA has a policy orientation, advising governments on how to shape educational policy, while TIMSS has a research orientation, focusing on the impact of instructional practices in the classroom. However, in practice both studies influence policy development, albeit with somewhat difference emphases.

In TIMSS 1995, students in Second year in Ireland achieved a mean score of 527 (SE = 5.1). This did not differ significantly from the average of OECD countries in the study (OECD, 1997), ranking 8th among 17 participating OECD countries. The performance of students in Ireland was significantly higher than on the test as a whole in three content areas: Fractions and Number Sense; Data Representation, Analysis and Probability; and Proportionality. Performance was significantly lower in two areas: Geometry and Algebra. Students in Ireland performed at about the same level as on the test as a whole on Measurement (OECD, 1997). Students in Ireland also achieved a mean score on science (538) that was not significantly different from average for participating OECD countries (537). Performance was significantly higher than on the test as a whole three content areas (Earth Science, Life Science and Environmental Issues and the Nature of Science), and significantly less well on two (Physics and Chemistry). No gender differences were observed in Ireland on TIMSS mathematics, overall or by content area, but male students outperformed females on the overall science scale, and on the Physics content area.

Results for TIMSS 2015 were published in late November 2016 (see Clerkin, Perkins and Cunningham, 2016) and, when combined with PISA 2015 outcomes, allow for an in-depth analysis of the performance of post-primary students in Ireland on mathematics and science, as well as the broader instructional and home environments in which development in these subjects is supported.

2.1.6. PIAAC 2012

In 2012, adults aged 16-64 years in 25 countries/jurisdictions participated in the Programme for the International Assessment of Adult Competencies (PIAAC), including Ireland. Like PISA, PIAAC is run by the OECD. It involved the assessment of reading literacy, numeracy, and computer-based problem solving. Adults in Ireland achieved an adjusted[20] mean score of 265 on reading literacy, which was below the study average of 270 (CSO, 2013). The highest-performing countries on the literacy test were Japan (298) and Finland (294), while Germany, Poland, Flanders (Belgium) and Northern Ireland had scores that were not significantly different from Ireland's. In Ireland, 17.9% of adults performed below Proficiency Level 2 on reading literacy, compared with a study average of 16.7%. The mean score of adults in Ireland on numeracy (255) was also significantly below the country average (266). In Ireland, 25.6% performed below Level 2 on numeracy, compared with a study average of 20.2%. Hence, Ireland's performance was relatively poorer on numeracy, compared

[20] Scores were adjusted by assigning a fixed score (85) to all adults who did not complete the PIAAC survey for literacy-related reasons. In practice, adjusted mean scores are not very different from unadjusted mean scores, which do not factor in the performance of adults unable to attempt the PIAAC tests (CSO, 2013).

with literacy. On an assessment of problem-solving in technology-rich environments, for which mean scores were not generated, 42.0% of adults in Ireland performed at the lowest proficiency level, compared with a study average of 41.7%. These include adults who did not take the PIAAC tests on computer, of whom there were more in Ireland than on average across countries in the study. A comparison of the literacy performance of adults aged 26-28 years old (a large proportion of whom would have been in the PISA 2000 cohort in their country) found that adults in this age range in Ireland performed less well on PIAAC than on PISA, suggesting a deterioration of skills since post-primary schooling. Similar findings emerged when the PISA and PIAAC reading literacy scores of adults in other age ranges (17-19 years, 20-22 years, and 23-25 years) were examined (i.e., those who would have been in the PISA 2003, 2006, 2009 and 2012 PISA cohorts). However, it should be noted that the comparisons did not involve a direct link (e.g., common items) between the two studies.

2.2. Factors Associated with Performance on PISA

This section examines factors associated with performance on earlier cycles of PISA, with a particular emphasis on PISA 2006 when, as in 2015, science was a major assessment domain (see Eivers, Shiel & Cunningham, 2006, for additional details). The section looks at school-level and student-level characteristics associated with performance, and then looks at outcomes of a multi-level model of performance based on PISA 2006 science.

2.2.1. School characteristics

In PISA 2006, 17.2% of the variation in science performance was between schools, while on average across OECD countries, it was 32.7%. Countries with lower between-school variance than Ireland included Finland (5.9%), Norway (10.5%), and Sweden (12.2%). A factor associated with high between-school variance (e.g., 54.6% in Austria at and 56.7% Germany) is the allocation of students to vocational or academic tracks (school systems) at an early age. This differs from the situation in Ireland, where all students take a common syllabus (albeit at different levels of complexity) and do not specialise in vocational or academic subjects until a later stage of schooling, if at all. In Ireland, economic, social and cultural status (ESCS), the OECD's measure of socioeconomic status, accounted for 67.4% of the variation in science performance between schools, and just 10.1% of the variation within schools. On average across OECD countries, 62.2% of between-school differences were accounted for by ESCS, with additional variance explained by study programme (a factor that did not explain between-school differences in Ireland). ESCS explained an average of 9.0% of within-school variance across OECD countries (OECD, 2007, Table 4.1a). Other school-level variables associated with science performance in Ireland in 2006 included:

- School disadvantaged status – schools in the School Support Programme under DEIS achieved a mean score of 479.8[21] on PISA 2006 science, compared with a mean score of 517.9 for students on other schools. The difference (38.1 score points in favour of students in other schools) was statistically significant.
- School sector – students attending secondary schools (521.3) had a significantly higher mean science score that students attending community/comprehensive (501.3) or vocational (480.7) schools.

[21] These mean scores can be interpreted with reference to the OECD mean of 500 and standard deviation of 100 established for science in 2006 and the mean and standard deviation for Ireland (508.3 and 94.4) in the same PISA cycle.

- School size – schools in PISA 2006 were categorised as large (more than 80 15-year-olds enrolled), medium (41-80) and small (fewer than 41). Large schools had a significantly higher mean science score (519.0) than either medium (488.9) or small (4713) schools.
- School gender composition – Students in all-male and all-female schools had an identical mean score (522.0), which was significantly higher than the mean score of students in mixed schools (498.4).

2.2.2. Student background characteristics

Student-level factors associated with performance on science in PISA 2006 in Ireland included:

- Language spoken at home – students who spoke English or Irish at home had a significantly higher mean score on science (510.8) than students who spoke another language (449.6), with just 2% reporting that they spoke another language.
- Number of siblings – students with one sibling had a significantly higher mean science score (522.5) than those with three siblings (505.5) and four or more (483.8), and did not differ significantly in performance from those with none (519.9).
- Parental education – Students with at least one parent whose highest level of education was upper secondary had a significantly higher mean score (494.4) than students of parents whose highest level was primary (440.2) or Junior Cycle (476.6), and a significantly lower mean score than those whose parents' highest level of education was a third-level certificate or diploma (519.9) or a third-level degree or post-graduate degree (544.1).
- Economic, social and cultural status (ESCS) – students in Ireland in the top third of the OECD's index of socioeconomic status had a mean science score (548.1) which was significantly higher mean score than students in the middle third (507.8) and in the lowest third (472.8).
- Books in the home – students with 26-100 books in their home had a significantly higher mean score (503.0) than students with 0-10 (434.2) and 11-25 (466.3) books, and a significantly lower score than students with higher numbers of books. For example, students with over 500 books had a mean science score of 551.3.
- Level of interaction with parents – students in the top third of the Index of parental interaction (including more frequent discussions on political and social issues, more discussions on books, films or TV programmes, and eating dinner around the table more frequently) had a significantly higher mean score (531.6) than students in the middle third (518.8) and the lowest third (490.8).
- Grade level – students (aged 15 years) in Transition year had a significantly higher mean score (537.1) than students in Second year (408.5), Third year (499.3) or Fifth year (519.6).
- Attendance at school – students with no absences in the two weeks prior to PISA had a significantly higher mean score (521.7) than those absent for 1-2 days (508.6), 3-4 days (470.3) or longer.
- Uptake of science – students who had taken the Higher-level science examination at Junior Certificate (63.9% of the cohort) achieved a significantly higher mean score (550.9) than

students who took Ordinary level (27.6%, 441.1) and those who did not take the examination (8.4%, 444.0).

2.2.3. Students' attitudes and engagement

In PISA 2006, a number of attitudinal and motivational variables that could be compared across countries were associated with science performance among students in Ireland:

- General Value of Science – an index of general value of science was constructed based on students' level of agreement with statements such as 'science is valuable to society' and 'advances in science and technology usually improve people's living conditions'. Students in the top quartile of the PISA value of science index in Ireland achieved a mean score that was some 81.8 points higher than that of students in the bottom quartile.
- Self-efficacy in Science – an index was constructed based on students' reports of the ease with which they could complete tasks such as 'I can explain the role of antibiotics in the treatment of diseases' and 'I can identify the better of two explanations for the formation of acid rain'. Students in the top quartile of the self-efficacy index in Ireland had a mean score that was significantly higher, by 110.3 score points, than that of students in the bottom quartile.
- Awareness of Environmental Issues – an index was constructed based on students' reported level of familiarity with environmental issues such as the increase of greenhouse gases in the atmosphere, nuclear waste, and use of genetically-modified organisms. Students in the top quartile of the index in Ireland achieved a mean science score that was some 104.5 points higher than that of students in the bottom quartile.

Additional attitudinal variables, deemed to be comparable within countries only, included General Interest in Science, Instrumental Motivation to Learn Science, Enjoyment of Science, Engagement in Science-related Activities and Future-orientated Motivation to Learn Science.

In general, science attitudinal and engagement variables correlated at least moderately with science performance, ranging from 0.34 (General Value of Science) to 0.45 (Self-efficacy). Correlations on the national variables ranged from 0.26 (Engagement in Science-related Activities) to enjoyment of science (0.40). The correlation between Instrumental Motivation to Learn Science and performance was 0.28.

A number of the scales showed gender differences. Male students in Ireland had significantly higher scores on General Value of Science, Self-efficacy and Awareness of Environmental Issues, as well as on Engagement in Science-related Activities. Females had higher mean scores on General Interest in Science, Instrumental Motivation to Learn Science and Future-orientated Motivation to Learn Science. The difference between males and females on Enjoyment of Science was not statistically significant.

2.2.4. Multi-level models of performance

In addition to examining associations between single variables and performance, analysis of PISA 2006 data in Ireland involved the construction of multi-level models of science performance (e.g., Cosgrove & Cunningham, 2011). Such models can examine the effects of a variable or an interaction between variables on performance, while holding the effects of other variables constant. Cosgrove and Cunningham reported that their model explained almost half of the overall variance in science performance (79% between schools, and 42% within schools). In their final model, two school-level factors remained: school social composition (based on the average percentage of students in a school availing of a Junior Certificate examination fee waiver) and promotion of science (participation of the school in science competitions). The final model included five clusters of student variables: demographic variables (gender, grade level and number of siblings), socioeconomic/language variables (parental SES, home language), home climate (number of books in the home), engagement in school and school science (study of science, and intent to complete the Leaving Certificate), and general engagement in science (looking at science websites, reading science article or magazines, expecting a science career by age 30, enjoyment of science, and self-efficacy in science). While most effects were positive, negative effects were observed for looking at websites and being in Second, Third or Fifth year, compared with Transition year. Girls who did not study science had a higher mean score than boys who did not study science. It is notable that variables such as enjoyment of science, reading science articles or magazines, and expecting a science career at age 30 explain additional variation in science performance, after accounting for school and student socioeconomic factors. Gilleece, Cosgrove and Sofroniou (2012) extended this work by analysing the equity of outcomes in PISA 2006 science (and mathematics) in Ireland using multi-nomial models of performance.

2.3. Recent Policy Initiatives Relevant to PISA

This section looks at the policy context of PISA in Ireland. It describes some policies that have been in place for a number of years prior to 2015, and others that have been implemented more recently, or are about to be implemented, and hence may be expected to impact on performance in future cycles of PISA.

2.3.1. National Strategy to Improve Literacy and Numeracy 2011-2020

In 2011, in response to concerns about standards in reading literacy and mathematics, the Irish Department of Education and Skills launched the *National Strategy to Improve Literacy and Numeracy Among Children and Young People 2011-2020 (DES, 2011)*. The Strategy included a number of measures designed to improve performance in these areas at post-primary level, including:

1. Increasing the duration of initial teacher education (the Post Graduate Diploma in Education) to a minimum of two years

2. Ensuring that initial teacher education programmes include topics relevant to literacy and numeracy development including children's language acquisition, teaching literacy and numeracy, teaching digital literacy skills, teaching children with special and additional learning needs, using diagnostic assessment, and using formative and summative assessment activities in literacy and numeracy

3. Providing access to approved professional development units on literacy and numeracy across the curriculum for second-level teachers (as an element of continuing professional development)

4. Ensuring that the revised English syllabus at Junior Cycle provides for the development of literacy in a range of texts (literary and non-literary) and a range of media, including digital media, and ensuring that reading tastes of boys are catered for

5. Continuing with the dissemination of the new post-primary mathematics syllabus ('Project Maths') syllabus, which was already underway prior to the Strategy

6. Requiring all post-primary schools to administer standardised tests of English reading and mathematics to all eligible students at the end of Second year.

In addition to these measures, some of which had been implemented prior to PISA 2015, the Strategy included specific targets for improved performance on PISA by 2020, including (compared with PISA 2009), a halving of the proportion of students performing below Proficiency Level 2, and an increase of 5% in the proportion performing above Level 4. In 2009, 17.2% of students in Ireland performed below Level 2 on PISA reading literacy, and this dropped to 9.8% in 2012. The proportion performing at Level 4 or higher increased from 28.9% in 2009 to 37.4% in 2012. In mathematics, 20.9% performed below Level 2 in 2009, and this dropped to 16.9% in 2012, while the proportion performing at Level 4 or above increased from 25.1% in 2009 to 31.0% in 2012. Hence, while the targets in reading literacy and mathematics for high achievers have already been met, further progress is needed to meet the targets for lower achievers. At the time of writing, an updated National Strategy, to be released in early 2017, is being prepared.

2.3.2. Junior Cycle reform and syllabus change

In 2015, the Department of Education and Skills (DES, 2015) issued a *Framework for Junior Cycle* that provided a theoretical basis for some forthcoming changes to the Junior Cycle programme. The Framework outlines 24 statements of learning, eight key principles and eight key skills that are at the core of the new Junior Cycle, and would be expected to cut across subject areas. Several of the statements of learning seem to support the broad view of literacy underpinning PISA (as outlined in Chapter 1), including the development of positive dispositions and the ability to use technologies for a range of relevant purposes. The statements (original numbering preserved) are:

- communicates effectively using a variety of means in a range of contexts in L1
- creates, appreciates and critically interprets a wide range of texts
- recognises the potential uses of mathematical knowledge, skills and understanding in all areas of learning
- describes, illustrates, interprets, predicts and explains patterns and relationships
- devises and evaluates strategies for investigating and solving problems using mathematical knowledge, reasoning and skills
- observes and evaluates empirical events and processes and draws valid deductions and conclusions
- values the role and contribution of science and technology to society, and their personal, social and global importance
- uses appropriate technologies in meeting a design challenge
- uses technology and digital media tools to learn, communicate, work and think collaboratively and creatively in a responsible and ethical manner.

Among the key skills that are especially relevant to PISA are;

- Communicating – which includes using language, number and digital technology

- Being literate – developing understanding and enjoyment of words, reading for enjoyment and with critical understanding, writing for different purposes, expressing ideas accurately and clearly, and exploring and creating a variety of texts, including multi-modal texts
- Being numerate – expressing ideas mathematically; estimating, predicting and calculating; developing a disposition towards investigating, reasoning and problem solving; gathering, interpreting and representing data; and using digital technology to develop numeracy skills and understanding
- Managing information and thinking – gathering, recording, organising and evaluating information and data, reflecting on and evaluating learning, and using digital technology to access, manage and share content.

The integration of these elements throughout different subject areas should result in greater overlap with the skills and dispositions found in other similar frameworks such as the Key Competencies Framework (European Commission, 2012), the 21st Century Skills Project (Griffin, McGaw & Care, 2012), and the Definition and Selection of Key Competencies Project (Rychen & Salganik, 2003), as well as in PISA. The focus on student well-being in the statements and key skills is also consistent with the increased emphasis on this area in PISA.[22]

The Junior Cycle framework and the new syllabi in English and science signal important changes in assessment, with students expected to participate more actively in the assessment process on a more on-going basis. An important aim of the English syllabus (NCCA/DES, 2013, 2015) is for students 'to use their literacy skills to manage information needs and to find, use, synthesise, evaluate and communicate information using a variety of media' (p. 5). In science (NCCA/DES, 2015), students are encouraged to 'develop key skills … to find, use, manage, synthesise, and evaluate data; to communicate scientific understanding and findings using a variety of media; and to justify ideas on the basis of evidence' (p. 5). Hence, the idea of developing sets of transferable skills that are relevant to life-long learning permeates both syllabi. While none of the students in PISA 2015 had studied under the new syllabi (English was introduced in first year in September 2014 and science in September 2015), the new syllabi, and, most importantly, the development of the skills dispositions underpinning them, may well impact on the performance and attitudes of students in future PISA cycles.

2.3.3. New mathematics curriculum for post-primary schools

The new mathematics curriculum for primary schools ('Project Maths'), was implemented in post-primary schools in Ireland on a phased basis between 2008 and 2015. On its website, the National Council for Curriculum and Assessment (NCCA, 2016) describes Project Maths as 'an exciting, dynamic development in Irish education. It involves empowering students to develop essential problem-solving skills for higher education and the workplace by engaging teenagers in mathematics set in interesting and real-world contexts'. According to the NCCA (2012), students are 'encouraged to think about their strategies, to explore possible approaches and evaluate these, and to so build up a body of knowledge and skills that they can apply in both familiar and unfamiliar situations' (p. 18). Coupled with the implementation of the new curriculum in schools, both Junior and Leaving

[22] The OECD will issue a report on well-being in 2017, based on student responses to items dealing with well-being on the PISA 2015 School, Student and Parent Questionnaires. It is planned to include a stand-alone Student Well-being Questionnaire in PISA 2018.

Certificate examination papers were up-graded to incorporate changes to syllabi, and significant investment was made in upskilling teachers and providing resources (see www.projectmaths.ie).

To date, information on the effects of the new curriculum has been limited, though it is acknowledged that the initiative is still in its early stages. The official evaluation, conducted by the National Foundation for Educational Research in England (Jeffes et al., 2013), using released items from international studies, including TIMSS and PISA, found that ‘overall, schools following a greater number of strands, or schools having a greater experience of teaching the revised syllabus, does not appear to be associated with any improvement in students’ achievement or confidence’ (2013, p. 5). Moreover, there was a lack of evidence of the processes underpinning the new curriculum in students’ written classwork.

As noted in Chapter 1, an expanded sample in PISA 2012 included all 23 initial Project Maths schools (those that implemented the revised syllabus first, in the period 2008 to 2010). Students in initial schools achieved a mean score of 505.3 score points, while those in non-initial schools achieved a mean score of 501.3. The four-point difference was not statistically significant. The pattern of non-significantly higher mean scores extended to the three PISA 2012 mathematical processes (Formulating, Employing and Interpreting) and to the four content areas (Change and Relationships, Space and Shape, Quantity and Uncertainty and Data). Performance in initial schools was strongest on Space and Shape (485.8), and was not significantly different from the OECD average of 489.4, whereas the mean score of students in non-initial schools (477.4) was significantly lower.

Although PISA 2015 might seem like a good opportunity to monitor the effects of new curriculum on students’ mathematical performance and attitudes, there are a number of difficulties. First, PISA mathematics is a minor assessment domain in 2015, so detailed information on mathematics content areas and processes, and on students’ attitudes towards mathematics, is not available. Second, the transfer to computer-based testing could mask other changes in performance, as students may not be familiar with the new interface. Third, other initiatives implemented in recent years, such as the allocation of an additional 25 CAO points for all students achieving a Grade D3 or higher[23] on Leaving Certificate Higher-level mathematics, may have had an effect on student performance.

2.3.4 Digital Strategy and related initiatives

A number of recent national and international reports on Information and Communication Technology (ICT) infrastructure and usage in post-primary schools in Ireland (e.g., European Schoolnet & University of Liege, 2012; Cosgrove et al., 2014; OECD, 2015a) indicate that, although computer-usage by teachers to plan for and implement instruction is relatively strong, student usage of computers in school is limited relative to other European and OECD countries, and there are significant gaps in infrastructure and maintenance. Recent initiatives, such as the provision of a 100 megabytes per second (Mbps) broadband connection in all post-primary schools (see McCoy, Lyons, Coyle and Darmody, 2016) represent a beginning, with much remaining to be done if ICT is to be integrated effectively into teaching and learning in all schools and subject areas. The use of technology to deliver assessments has also been limited, although, recently, the Educational Research Centre and some UK publishers have made computer-based tests of ability and achievement available to post-primary schools.

[23] This is H6 from 2017 onwards.

The launch of the *Digital Strategy for Schools 2015-2020* by the Department of Education and Skills (2015) provides a roadmap for development in four broad areas: teaching, learning and assessment using ICTs; teacher professional learning; leadership, research and policy; and ICT infrastructure. Students who participated in PISA 2015 will not have had full benefits of 100 Mbps broadband as its installation in schools was completed in 2014. Furthermore, as the Digital Strategy was launched after the implementation of PISA 2015 in schools, it will not have impacted on students' performance.

A number of recent reports, including the Department of Education and Skills' *Action Plan for Education 2016-19* (DES, 2015b), which has the increased use of ICT in teaching, learning and assessment among its goals, and the *Report of the STEM Education Review Group*[24] (2016), which outlines a set of proposed actions on the use of technology to enhance STEM learning, help to ensure that there is a continuing focus on the use of ICT for teaching, learning and assessment.

2.4. Summary and Conclusion

Ireland's overall mean score on PISA science has been significantly above the OECD average in all cycles to date. Performance was stable across the first four cycles, but increased significantly in 2012, when Ireland's mean score improved from 508.0 to 522.0. However, even then, Ireland lagged behind a number of high-performing countries/economies, including several East-Asian countries. In 2012, 10.8% of students in Ireland, compared with 8.4% on average across OECD countries, performed at the highest proficiency levels (Levels 5-6), while 11.1%, fewer than on average across OECD countries (17.8%) performed at the lowest levels (below Level 2). Also in 2012, male students in Ireland had a mean score that was not significantly different from females, while, on average across OECD countries, there was a small but significant difference in favour of males.

In four of the five PISA cycles prior to 2015, students in Ireland achieved a mean score on reading literacy that was significantly above the corresponding OECD average, and Ireland usually ranked among the top five OECD countries. The exception was 2009 when performance was not significantly different from the OECD average. In 2012, students in Ireland had a mean score of 523.2.[25] In the same year, just 9.6% of students in Ireland performed at or below Proficiency Level 1, compared with an OECD average of 18.0 percent. Ireland had 11.4% of students performing at Level 5 or higher, compared with an OECD average of 8.5 percent. Female students in Ireland in PISA 2015 achieved a mean score that was significantly higher than that of males, by 28.5 score points. This was lower than the OECD average difference of 37.6 points, also in favour of females. Students in Ireland did comparatively better on computer-based test of reading literacy offered as part of PISA 2009 than on the paper-based assessment, and did marginally less well on the computer-based test of reading literacy in 2012, compared with paper-based reading.

Ireland's mean score on PISA mathematics was not significantly different from the OECD average in 2003 and 2006. In 2009 (the same cycle in which there was a large decline in reading literacy), it was significantly below the OECD average. In 2012, it was significantly above the OECD average for the first time. In 2012, 16.9% of students in Ireland and 23.0% on average across OECD countries performed at or below Proficiency Level 2, while 10.7% performed at Level 5 or above, compared with 12.6% on average across OECD countries. Hence, even though Ireland performed above the OECD average in 2012, it had fewer students performing at the highest proficiency levels, compared

[24] STEM: Science, Technology, Engineering and Mathematics.
[25] This is back-linked to a scale with a mean of 500 and a standard deviation of 100 that was established when reading literacy was a major assessment domain in 2000.

with the corresponding OECD average. In PISA 2003 and 2012 (the two years in which mathematics has been a major assessment domain), students in Ireland performed at a level that was below the OECD average on the Space and Shape content area, indicating that this is an area of particular weakness. In PISA 2012 in Ireland, male students had a mean score that was significantly higher than that of females, by 15.3 score points. This was greater than the average difference of 10.7 points in favour of male students, on average across OECD countries. Students in Ireland did relatively less well on an optional computer-based assessment of mathematics in PISA 2015, compared with their performance on paper-based mathematics.

Performance by Irish adults aged 16-64 on the PIAAC adult literacy assessment in 2012 was below the country average on both reading literacy and numeracy in 2012. A cause of concern is the relatively weak performance of young adults who would have been eligible to participate in PISA (as 15-year-olds) in 2000-2012. However, as was noted, direct links have not been established between PIAAC and PISA literacy, while the option of using computers in PIAAC may have had an impact on the performance of some participants.

A number of variables have been found to be associated with science performance in earlier rounds of PISA in Ireland, including 2006, when science was also a major domain. At school level, these include school disadvantaged status (with students in schools designated as disadvantaged (now DEIS) doing less well on average than students in non-disadvantaged schools), school sector (with students in secondary schools outperforming those in other school types), school size (with larger schools doing better), and school gender composition (with students in all-male and all-female secondary schools outperforming students in other school types).

Individual-level variables associated with science performance in Ireland include language spoken at home (with speakers of English or Irish doing better), number of siblings (with students who have one sibling doing better on average than those with three or four or more siblings), parental education (with children of degree holders outperforming parents with other attainment levels), economic, social and cultural status (with students with higher levels of ESCS doing better), number of books in the home (with students with more books doing better), level of interaction with parents (with students who interact more often doing better), grade level (with students in Transition year doing better, compared with other grade levels), uptake of science (with students taking Higher-level science at Junior Certificate level doing better than students taking Ordinary level, and students not taking science as a subject). A number of student attitudinal and engagement factors are also positively associated with science performance including General Value of Science (a perception that science is valuable to society), Self-efficacy in Science (based on students' confidence to explain key science concepts), Awareness of Environmental Issues, Instrumental Motivation to Learn Science, Enjoyment of Science and Engagement in Science-related Activities. Males achieved higher scores than females on the PISA indices of General Value of Science, Science Self-efficacy, Awareness of Environmental Issues, and Engagement in Science-related Activities. Girls had higher scores on General Interest in Science, Instrumental Motivation to Learn Science, and Future-orientated Motivation to Learn Science.

Multi-level models of performance on science confirm that there is a positive association between school-level socioeconomic status and science, while controlling for the effects of other relevant variables. At the individual level, demographic variables (gender, grade level and number of siblings), socioeconomic/language variables (parental SES, home language), home climate (number of books in the home), and engagement in school science and general engagement in science (reading science articles or magazines, expecting science career by age 30) all explain some variance, both between and within schools.

A number of recent policies related to education in Ireland are relevant to performance on PISA. Some of these, such as the *National Strategy to Improve Literacy and Numeracy* and Project Maths are already in place and may impact on performance in PISA 2015, though the ways in which computer-based assessment interacts with actions arising from these policies needs to be taken into account (for example, while there may be some emphasis on the use of ICT in mathematics arising from Project Maths, they do not feature heavily in assessment contexts). Other initiatives, such as the Junior Cycle Framework (2015), revised syllabi in English and science at Junior Cycle level, the Digital Strategy for Schools 2015-2020, and the Action Plan for Education 2016-2019 were launched after 15-year-olds in schools had participated in PISA 2015, and these actions may impact on the performance of students in future cycles of PISA.

Chapter 3: The Transition to Computer-based Testing in PISA

This chapter looks at the transition to computer-based testing in PISA 2015, and considers how the literature on computer-based testing can contribute to an understanding of performance in Ireland and other countries in PISA 2015. First, the literature comparing paper-based and computer-based testing is summarised. Second, computer-based testing in earlier PISA cycles is described. Third, details of the PISA 2015 Field Trial mode study are given. Fourth, the outcomes of a review of PISA 2015 computer-based science items by an expert group at the Educational Research Centre are presented. The chapter concludes with a summary.

3.1. Comparisons of Paper-based and Computer-based Tests

Currently, most tests and examinations in Ireland are administered on paper. However, international developments on the use of technology are starting to transform the assessment landscape. A particular focus has been the transition from paper-based to computer-based tests. According to Thompson, Turlow and Moore (2003), the advantages of computer-based tests include more efficient test administration, the immediate availability of results, and student preference in favour of such tests. Other features include the potential for built-in student accommodations, the inclusion of increasingly-authentic or real-life items, and the potential to make assessment adaptive (that is, tests that are tailored to the student's ability level). A particular concern relates to mode effects – differential examinee performance that can occur due to differences in the presentation of items on computer-based and pencil-and-paper versions of a test (Wang, Jiao, Young, Brooks & Olson, 2007). Factors that could change the testing experience include screen size, font size, resolution of graphics, the option of reviewing or revising previous responses, and students' attitudes towards taking tests on computer compared with paper.

According to assessment standards (e.g., AERA, APA & NCEM, 2014), test developers who make the transition to computer-based testing should provide direct evidence of score interchangeability, when different items, testing materials, procedures, or test forms are administered in different formats. Furthermore, to avoid 'construct-irrelevance variance', the standards suggest that even experienced test takers should be provided with training that will help them manage the specific details of the test's interface. Such practice may need to be provided prior to test administration.

A number of studies have compared performance on paper-based and computer-based tests, and the conclusions reached have been mixed. Several researchers (Singleton, 2001; Wilhelm & Schroeder, 2008; and Zandvliet & Farragher, 1997) have reported that computer-based and paper-based tests are psychometrically equivalent. Meta-analyses of the effects of testing modes on performance on reading and mathematics tests completed by K-12 students in the US reported no statistically significant mode effects (Wang et al., 2007, 2008). However, while Peak (2005) reported little or no effect of mode of administration across grades and subjects, she identified two areas where differences remain – long passages in reading (perhaps due to a requirement to scroll through the text, and restrictions on reading comprehension strategies such as underlining key information) and graphical questions in mathematics. Russel (1999) reported that performance was similar on paper- and computer-based tests for multiple-choice items in language, mathematics and science at grades 6-8, but that performance was better on computer for science and language tests with short answers. Students completing extended writing tasks also fared better on computer.

A common finding in the literature is that that females may experience an increase in 'stereo type threat' under computer-based testing conditions, which may negatively affect their performance (e.g., Gallagher, Bridgeman & Callahan, 2000; Koch, Müller & Sieverding, 2008). According to the OECD (2005), more advanced cognitive tasks on computers such as programming are associated with greater gender differences in favour of males, pointing to a need to increase interest and confidence among females (rather than focusing on specific skills, which they may have acquired already). In the PISA 2012 reading in Ireland, female students outperformed males on paper-based reading, by 28.5 score points. The corresponding difference on computer was marginally smaller, at 25.3. In PISA 2012 in Ireland, the gender difference in favour of boys was slightly smaller on paper-based mathematics (15.3 points), compared with computer-based mathematics (18.6). A similar finding emerged on average across OECD countries, where the respective differences in favour of boys were 10.7 (paper) and 12.5 (computer). These data suggest that, where gender differences already exist on paper-based tests, they may increase a little on computer-based versions.

A number of studies have investigated the effects of familiarity with computers on performance. For example, Zhang et al. (2016) found that home computer access was positively related to performance on computer-based tests of writing, mathematics and technology and engineering literacy at Grade 8 in the National Assessment of Educational Progress in the US, even after factors such as socioeconomic status, race/ethnicity, gender and computer usage were taken into account. Two specific computer usage factors emerged from the data: students' use of different types of mathematics-related computer programmes at school and their general use of computers for mathematics practice. These student usage factors were negatively associated with performance, perhaps because lower-achieving students may use mathematics-specific computer programmes for learning support purposes. A similar finding was reported by the OECD in their analysis of PISA 2012 mathematics performance, where frequent practice was not associated with higher performance (2015a).

Zhang et al. also replicated their analyses using the 2011 NAEP mathematics paper-based assessment (also administered at Grade 8). They found that access to a computer at home and mathematics-related computer use exhibited similar relationships to performance (in terms of direction and magnitude), leading them to conclude that administration mode may not be the underlying factor that explains the patterns found between computer access and use and math performance on computer-based tests of mathematics.

Some specific features of computer-based tests can also present challenges. Mason, Patry and Bernstein (2001) found students' performance can be negatively affected if there is no opportunity to review and check responses. Bennett (2003) found that screen size affected scores on verbal reasoning tests, perhaps because smaller screens require scrolling.

3.2. Computer-based Assessments in Earlier PISA Cycles

As part of PISA 2006, the OECD offered an experimental test of computer-based science (CBAS).[26] While CBAS was not offered in Ireland as part of the PISA 2006 Main Study, Ireland did take part in the option in the PISA 2006 Field Trial (in spring 2006), along with eleven additional countries.[27]

[26] Originally, it had been planned to administer a computer-based test of reading literacy. However, when this became too complex, the focus switched to science.

[27] The countries that participated along with Ireland were Australia, Austria, Chinese-Taipei, Denmark, Iceland, Japan, Korea, Norway, Portugal, Slovak Republic, and the Russian Federation. Three countries took part in CBA in the PISA 2006 Main Study – Denmark, Iceland and Korea.

Ireland also took part in computer-based assessments of reading literacy in PISA 2009 and 2012, and mathematics and creative problem solving in PISA 2012.

3.2.1. The CBAS field trial in 2005

This Field Trial had two key aims: to ascertain the feasibility of implementing an assessment of science on computers in an international context; and to investigate whether, and to what extent, CBAS adds value to the existing paper-based assessment. CBAS was of interest because it could provide information on whether students' engagement and motivation were higher on computer- than on paper-based science.[28] It had a number of other interesting features. It could allow for: a wider range of stimulus materials and response formats than on paper, thereby offering the opportunity to assess a broader range of skills; increased use of non-text stimulus materials that could reduce reading load; computer-based items that could tap into investigative approaches to science, such as simulations and experiments with variables that students could manipulate; and the software that could provide information on students' test-taking behaviours.

The CBAS sample for Ireland was a convenience sample. All 30 selected schools were in Dublin city and county. Each of 320 participating students completed an hour of paper-based science first, and then an hour of CBAS, or vice versa. Test administrators administered CBAS using laptops connected to a wireless network, and via test delivery software loaded onto the test administrator's computer. Students could access the test by logging on. A rotated test design was used, with items bundled into half-hour blocks and students attempted various combinations of these. The school participation rate after replacement was 100%, while 83% of selected students took part. Depending on availability of laptops, either ten or twenty students were selected in each school. The test was administered using 50 Dell D600 laptops with 512 Mb of RAM, a 40GB hard disk, an 802.11g wireless, Windows XP Professional, and headphones.

In Ireland, 89.3% of students agreed or strongly agreed that taking part in CBAS was enjoyable, compared with 54.9% expressing similar views about the paper-based test. Three-fifths (59.1%) reported that they would take CBAS just for fun, compared with 35.6% reporting that they would take the paper-based test just for fun. Two-thirds reported putting the same amount of effort into both assessments, while 20% said they put more effort into CBAS, compared with 11% for the paper-based test. Gender differences across attitudinal items were small, with marginally more females (91.8%) than males (87.1%) reporting that they enjoyed CBAS. Slightly more females than males (58.4% vs. 51.7%) reported that they enjoyed doing the paper-based test, while 62.6% of females, compared with 54.9% of males, said they would take CBAS for fun. In contrast, 41.4% of females, and just 26.2% of males said they would take the paper-based test for fun. There was no gender difference in the amount of effort put into CBAS by male and female students. On the other hand, it was found that male students exhibited more behaviours than females during CBAS (for example, by playing and replaying a film clip that formed part of the stimulus text).

Of the 116 CBAS Field Trial items, 25 exhibited differential functioning, with 12 favouring females, and 13 favouring males. Male students outperformed females on CBAS. It was hypothesised that the difference could have arisen from the greater familiarity of males with computers, as 60% of males, but only 40% of females, rated themselves as being familiar with computers. Overall, and consistently across participating countries, male students did better on CBAS than on the paper-based test, while there was no gender difference on the paper-based test. While there was a difference on CBAS in favour of males who were familiar with computers, compared with females,

[28] The paper-based test did not contain the same items as CBAS.

there was no difference between these two groups on the paper-based test. Across both CBAS and the paper-based test, males performed less well than females on items described as having a high reading load. Since the computer-based items required less reading than the paper-based ones, this may have helped males. Males' stronger preference for computer-based testing, compared with females, was not associated with performance. Male students interacted with embedded media in CBAS more frequently than female students.

In Ireland, the correlation between performance on the two assessments was .70. This was lower than the correlations between reading literacy and mathematics, mathematics and science, and reading literacy and science (about 0.90 in all cases) in earlier PISA cycles.

Cosgrove and McMahon (2005) concluded that schools provided strong support for CBAS, arising from its innovative nature, and that implementation was successful despite some logistical and time challenges. However, they also acknowledged that the exact value-added contribution of CBAS over paper-based testing was difficult to identify.

3.2.2. The CBAS main study in 2006

Just three countries, Denmark, Iceland and Korea, took part in CBAS as part of the PISA 2006 Main Study. Five key findings emerged from the study (OECD, 2010b):

- There was no evidence in any of the participating countries to suggest that overall group performance was affected by the method of test presentation (computer or paper-based). However, in Denmark only, there was a slight tendency for scores on the computer-based test to drop
- Males outperformed females on CBAS in all three countries. Females outperformed males in Iceland on the paper-based test, while males in Denmark outperformed females on the same test. Gender differences in performance could not easily be linked to motivation, enjoyment or familiarity with computers (all of which were higher among males)
- On CBAS, males found items with a shorter reading load easier than females. It is unclear why the computer-based presentation disadvantaged females
- Students on the whole enjoyed the computer-based test more than the paper-based test, and were more motivated to take another computer-based test than another paper-based test
- Although a relationship was found between reported effort and performance on the paper-based test, such a relationship could not be established for the computer-based test.

The findings of the PISA CBAS study may be relevant in interpreting the outcomes of PISA 2015 science. However, the contexts are somewhat different. The comparison in PISA 2006 was between paper-based and computer-based tests that contained different item sets. The issue in PISA 2015 was whether a computer-based test that included old paper-based items and new items specifically designed for computer-based assessment, could be linked back to the paper-based PISA science scale used in earlier PISA cycles from 2006 onwards.

3.2.3. The PISA assessments of digital reading in 2009 and 2012

As noted in Chapter 2, PISA implemented optional computer-based tests of reading literacy (digital literacy) in 2009 and 2012. The computer-based (digital) reading tests in 2009 and 2012 were based on the same underlying frameworks as the paper-based (print) tests administered in those years, but there was no overlap in terms of specific test units or items. Instead, the digital reading tests included multiple texts and web environments that would be difficult to replicate on paper-based tests.

In the case of Ireland, it is difficult to interpret the outcomes of digital reading in 2009, given that performance on print reading dropped by about one-third of an OECD average standard deviation compared with 2000. If there had been an underlying difficulty with sampling (which was ruled out by an independent review – see LaRoche and Cartwright, 2010), performance might have been expected to be broadly similar in the two modes. In fact, performance was significantly stronger, by 13.3 score points, on the digital reading test (Perkins et al., 2012). Another hypothesis, for which there is some support (Cosgrove, 2015) is that students in Ireland were more engaged on digital reading than on print reading (Cosgrove 2015). While some countries (like Ireland) performed better on digital reading compared with print reading, including Korea (+28.3), Australia (+21.7) and New Zealand (+16.5), others performed less well, including Poland (-37 on digital, compared with print), Hungary (-25.8), Chile (-14.8) and Austria (-11.7). The OECD country average score on digital reading (498.9) was significantly higher than for print reading (493.4).

The outcomes for digital reading in PISA 2012 were broadly similar to those of 2009. Some countries, such as Poland (-41.3), Hungary (-38.2) and Austria (-9.6) performed less well on digital compared with paper-based, while others, including Korea (19.4), Sweden (15.1) and the United States (13.6) performing better on digital reading. On average across OECD countries, performance was about the same on print reading (496.5) as on digital reading (496.9). In Ireland, performance on print reading (523.2) was slightly, but not significantly, higher than on digital reading (520.1). While it is accepted that, on average across OECD countries, performance on digital and print reading was about the same, there were some notable mode effects in some countries. Gender differences, mainly in favour of girls, tended to be smaller on digital reading, compared with print reading. On average across OECD countries in 2012, the gender difference on print reading was 37.6, while on digital reading, it was 26.0. Again, this masked variation within countries. In Ireland, gender differences in favour of females were about the same in the two modes: 28.5 score points on print reading, and 25.3 on digital reading. In Korea, females had a mean score on print reading that was 23.2 score points higher than for males, while on digital reading the difference in favour of females was a non-significant 7.2 score points.

3.2.4 The PISA computer-based assessments of mathematics and problem solving in 2012

The computer-based mathematics test in PISA 2012 was based on the same framework as the print-based test. However, like digital reading, it sought to tap into the affordances of technology, with, for example, items that required students to make charts from data, sort data efficiently, and transform images. Problem solving in PISA 2012 was designed to focus on generic real-world problems involving decision-making, systems analysis and design and trouble-shooting, rather than on problems embedded within specific subject areas or domains.

As noted in Chapter 2, Ireland performed significantly less well on computer-based mathematics (493.1) in PISA 2012, compared with paper-based mathematics (501.5) in the same cycle. On average across OECD countries, performance on computer-based mathematics (497.1) was significantly higher than on paper-based mathematics (494.0). Again, there were notable within country differences, though these tended to be smaller than for reading literacy, with, for example, Poland (-28.5), Israel (-14.2) and Slovenia (-11.6), like Ireland, doing less well on computer-based mathematics, and the United States (16.7), Sweden (11.7) and Norway (8.2) doing better. In line with this, gender differences in favour of males tended to be slightly larger on computer-based mathematics compared with paper-based. On average across OECD countries, males had a mean score that was higher than that of females by 15.3 points on paper-based mathematics, and 18.6 on computer-based mathematics. On average across OECD countries, the differences in favour of males were 10.7 and 12.5 score points respectively. It is unclear if the lower performance of students on Ireland on computer-based mathematics was due to a mode effect (perhaps based on limited exposure to computers during mathematics instruction, or limited experience with computer-based tests) or some other factor (such as a lack of proficiency on the types of tasks encountered on the computer-based mathematics test).

As was the case with paper-based problem solving in PISA 2003, students in Ireland achieved a mean score (498.3) on computer-based problem solving in PISA 2012 that was not significantly different from the average across OECD countries (500.1). While lower-achieving students in Ireland (those at the 10th percentile) performed at about the same level as students on average across OECD countries, higher performers (those at the 90th percentile) were marginally, though not significantly, below the OECD average (Perkins & Shiel, 2014). A number of countries that performed at about the same level as Ireland on print-based mathematics, including France, the United Kingdom and Italy, had significantly higher mean scores than Ireland on computer-based problem solving. In Ireland, male and female students did not differ significantly in terms of their problem-solving performance, though male students did marginally better (500.9 and 495.7, respectively). The size of the gender difference in Ireland (5.2 points) was also similar to the 28-country OECD average (6.6 points), although, unlike in Ireland, the OECD average gender difference is statistically significant.

This hypothesis that students in Ireland struggle with the application of problem solving skills is reinforced by the finding, reported by the OECD (2014), that performance on computer-based problem solving in Ireland was over 18 points lower than would be expected given the performance of students on the print assessments of mathematics, reading and science, and just under 10 points lower than expected when their performance on the computer-based assessment of mathematics and reading only is accounted for. It is unclear why students in Ireland underperform on problem solving. It may be some combination of lack of familiarity with computer-based environments, and difficulty or unfamiliarity with the reasoning tasks on the problem solving test. Perkins and Shiel (2014) noted the weak performance of students in Ireland on Space and Shape on PISA 2012 print mathematics, and suggested that students in Ireland may lack visualisation and spatial reasoning skills required to successfully complete problem solving tasks, whether on paper or computer, on mathematics tests or on generic problem solving tests.

3.3. The PISA 2015 Field Trial Mode Study

A mode-effect study was incorporated into the PISA Field Trial for the 2015 cycle by the OECD and its contractors (OECD, 2015b). The purpose of the study was to examine mode effects at international level. The numbers of participating students in each country was deemed too small to report on within-country mode effects. However, a broad summary of outcomes for Ireland is provided.

3.3.1. International comparison of mode effects

The goals of the 2015 Field Trial (administered in spring 2014 in most countries) were: to generate information about the quality of the data obtained and survey operations; to identify operational characteristics associated with the computer delivery platform; to examine the quality of the newlydeveloped items for computer-based delivery; and to evaluate the Field Trial data using item response theory scaling to establish if reliable, valid and comparable scales could be constructed. As noted in Chapter 1, the Field Trial design involved the random allocation of students in participating schools (of which there were 30 in Ireland), to one of three groups: paper-based administration of trend items (PBA-Trend); computer-based administration of trend items (CBA-Trend); and computer-based administration of new items (CBA-New). Across 72 countries, 23% of students did PBA-Trend, 33% did CBA-Trend and 43% did CBA-New. An analysis of background variables showed that the random assignment worked well across countries. The computer-based testing was also deemed to have gone well, as problems were encountered with fewer than 2% of items. Information was generated on timing and type and number of interactions and sequences of actions between students and questions. It was found that, across countries, the over-whelming majority of students were able to complete the items in the time allotted (two hours, divided into two one-hour segments), and levels of engagement were consistent across the four 30-minute clusters that students were presented with. No overall association between time used (recorded in milliseconds) and performance was observed across countries, but, within countries, higher-achieving students spent more time in solving items. It was also concluded that timing was driven by item and unit complexity and respondent (individual) differences, rather than by country or school differences.

The Field Trial found a decline in item omissions, relative to earlier paper-based PISA cycles. Furthermore, the position effect was reduced by between one-third and one-half on CBA compared with PBA, depending on domain. This was interpreted as providing evidence that CBA leads to better data quality. The availability of timing data on CBA also allowed for a clearer distinction to be made between omitted and not reached items, thereby reducing measurement error.

Trend item parameters were computed based on the previous five cycles of PISA (2000-2012) using item response theory (IRT) scaling methods. According to the OECD, there was 'outstanding consistency' between item parameters estimated in previous cycles and the 2015 Field Trial item parameters. Consistency was evaluated using item fit statistics (mean square and root mean square deviations) and correlations between item difficulties and item slopes (discrimination) across modes. The OECD reports a high level of consistency between item parameters derived from the parallel PBA and CBA tests administered in the Field Trial using the same statistical procedures. These outcomes were interpreted as indicating that, within modes, item parameters are generally consistent (invariant) across countries and over time. CBA-New science items were also found to scale well with few problematic items and good fit across countries.

An analysis of CBA-Trend and PBA-Trend items also showed consistency between the two. A correlation of .94 was reported between item parameters across modes and domains. This, combined with invariance of item parameters across modes, led to the conclusion that 'a statistical link could be established if results for countries doing CBA and PBA in the PISA 2015 Main Study could be put on the same scale' (OECD, 2015b, p. 4). Interestingly, problems were identified in the analysis of data for a Collaborative Problem Solving Test (in which Ireland had not participated), as there were lower than desired correlations across test units (indicating inconsistency within the test).

The Field Trial report acknowledged that, within each domain, there was a set of items for which invariance among item parameters did not hold. This was attributed to the increasing role of technology in defining domains and it was noted that, while the Field Trial analysis indicated that links could be established between paper- and computer-based tests for PISA 2015, it was likely that, in the future, advances in technology would continue to drive the development of newer items in each cycle, further complicating the measurement of trend. The report identified four key factors that could affect the interpretation of trends in the future: the proficiency distributions of students, the sample of students surveyed, operational aspects of the survey, and changes to the constructs being measured (arising, for example, from the affordances of new technologies).

In the course of the Field Trial analysis, a new hybrid scaling approach was tried out and found to be effective – a two-parameter logistic (2PL) item response theory (IRT) model for dichotomous data and a generalised partial-credit model for polytomous data, along with the one-parameter Rasch model and partial-credit Rasch model used in earlier PISA cycles. The correlation between country means as reported in international reports on earlier PISA cycles, and those obtained by calibrating all the available data in a comprehensive scaling was 0.998, indicating that the new scaling model could be extended to the Main Study.

3.3.2. National comparisons of mode effects

The PISA team at the Educational Research Centre carried out an initial analysis of Ireland's (unweighted) data, focussing on percent correct scores. Overall, there was a small mode effect in favour of PBA. Analysis at individual item level also suggested that a minority of items and, in particular, items from the reading domain, may incur positive or negative mode effects resulting from the adaptation of trend items from paper to computer. A few items had rather large effects (based on percent correct score differences) and these were tagged for further investigation in the context of the PISA Main Study.

The national PISA centre for England undertook an informal analysis of their national data (John Jerrim, personal communication, November 7, 2014). The analysis showed that a few of the same items as in Ireland and some different items incurred mode effects, possibly disputing the case of a cultural or language bias by mode. However, the sample sizes for the analyses of the English and Irish data were relatively small and non-representative, so robust conclusions could not be drawn.

3.4. A Review of PISA 2015 Science Items

Members of the PISA Advisory Group with expertise in science and Educational Research Centre staff reviewed a selection of PISA 2015 science items, comprising both trend items (those transferred to a computer-based platform from the original paper-based mode), and new items (those developed for computer-based assessment from the outset, including those described as interactive) in October 2016. The selection of trend items (and associated units) included some on which students in Ireland performed better on paper in earlier cycles compared with the 2015 computer-based version, and some on which they performed less well. The items that were reviewed also included some of the new interactive and non-interactive science items.[29]

[29] The units examined by the review group included two that were released by the OECD following the PISA 2015 Main Study and now appear on its website: Slope Face Investigation and Sustainable Fish Farming (see http://www.oecd.org/pisa/pisa-2015-science-test-questions.htm). No interactive items from PISA 2015 have been released as they will be administered in the 2018 Main Study. However, one of the interactive units from the PISA 2015 Field Trial, Running in Hot Weather, is also accessible on this site. Example items from the three units are also given in Appendix B.

The issues raised by the review group are presented under four categories: General presentation of questions, language and content, teaching and learning, and test-taking strategies.

It should be noted that many of the issues identified in the review (and described below) are also likely to have affected students in other countries participating in PISA 2015, although significant experience with computer-based learning in science and other curricular areas, and with computer-based assessment, could have mitigated the impact of some of these factors in some countries. It could also have been the case that high levels of science knowledge or science reasoning skills could have softened any potentially negative effects of computer-based testing for some students in some countries. The conclusions of the review group are summarised below under the headings of general presentation of questions, test language and content, teaching and learning experiences and test-taking strategies.

3.4.1. General presentation of questions

- The introductory stimulus in each unit appeared on the right-hand side of the screen, and was often repeated for more than one item in a unit (in the paper-based test, the stimulus appeared once only, at the beginning of the unit, but students could return to that page at any time). In some questions, additional stimulus material appeared on the left side of the screen, after the student has been referred to the right side, meaning that the student could have missed important additional information about the question. This was described as a 'flow of wording' problem. It means that students' attention may be misdirected to a fairly-lengthy text they have already read, possibly at the expense of focusing on a shorter segment that they need to read closely. It may also mean that scanning is precluded as a strategy, as otherwise students might not identify the specific information that a question is seeking.
- Some of the introductory information in the science units is quite detailed, on occasion extending over a number of screens. This could have led to information overload even before students started responding to items based on the unit.
- For the open-ended questions, the size of box in which students are expected to type text looks small on the computer screen (although students are informed that it expands if filled, and a scroll-bar appears for them to view their entire response during the general introduction to the assessment). On paper-based tests, students are given a space roughly equivalent to the expected length of their answers. This could lead students answering on computer to produce shorter responses than are required to adequately answer a question. It was noted that students may not know what specifically is expected of them when asked to 'explain', and need support on distinguishing between the need for a short comment and a more detailed explanation.
- After completing a unit or cluster of questions on computer, students could not return to review or modify their answers. On a paper-based test, they could have reviewed answers if, for example, time was available at the end of each hour of testing, or if they thought of the correct answer after moving on to a later unit. In the interactive units, students could not go back to the previous question within a unit.
- The requirement to correctly highlight rows of data generated by running a simulation to support the answer to a multiple-choice question or a question that combined multiple choice with a textbox to support an answer placed a significant burden on students not used to interpreting and evaluating complex data.

3.4.2. Test language and content

- When students encountered the instruction, 'tick one or more boxes', they may have marked just the first correct response and assumed that that was sufficient (i.e., ticking additional boxes to support an answer was optional). An instruction such as 'tick all that apply' might have worked better. Either way, students may have had limited experience of responding to questions with multiple correct responses.
- Students were faced with two complex tasks on the interactive items: running the experiments and applying science knowledge to interpreting the outcomes of the experiments in the context of the questions posed. Ability to impart science content knowledge (assuming it was present) may have been affected by students' ability to complete the interactive simulations, which represented a new item format for students in Ireland, in the context of science.
- The interactive simulations required some mathematics knowledge; students who are less proficient at mathematics could have struggled, regardless of their level of science knowledge.
- The environments presented in some units (e.g., Sustainable Fish Farming) might not be familiar to students in Ireland, who would be familiar with other ecosystems.

3.4.3. Teaching and learning experiences

- A majority of students in Ireland had not completed a test on a computer prior to taking the PISA 2015 tests (see Chapter 6), and this may put them at a disadvantage relative to students in other countries with similar levels of science knowledge, but higher levels of experience with computer-based tests.
- Although teachers in Ireland may have been taught how to implement technology to teach science in their college-based courses, the reality in many schools (e.g., lack of computers) means that they may not have had an opportunity to implement what they had learned, and hence their students may have missed out on acquiring key skills.
- Students might be expected to do better in the future on items such as those presented in PISA 2015 science, as their enquiry skills develop in the context of the revised Junior Cycle science syllabus. In particular, they can be expected to improve on identifying questions that can be answered by scientific research. Reviewers noted that students in Ireland may not be used to adopting a 'nature of science' perspective as they move through the test.

3.4.4. Test-taking strategies

- The strategy of reading the text/question, taking notes, and answering the question has changed with the introduction of computer-based testing. Reviewers who had been involved with the implementation of PISA in schools noted that most students tended not to take notes, and hypothesised that this could affect science and mathematics performance in particular. In preparing for paper-based examinations, students would have been taught to underline and highlight the key words. It is not feasible to do this with computers. For some students, the transition to computer may have meant 'breaking the habit of a lifetime'.
- Reviewers who had implemented PISA 2015 in schools noted that some students seemed to rush through the test. These students risked missing out on key aspects of a question,

sometimes nested in text repeated across a number of screens. The reviewers also noted that students tended to jump in and run the simulations rather than work their way into them more gradually and reflect on what was asked of them.

- Students may not have been exposed to simulation-style experiments in the past. Reviewers noted that doing the simulations was quite different to conducting and writing up an experiment. They also commented that the interactive items seemed to require high levels of engagement and concentration. However, anecdotally it was noted that student engagement does appear to have been high, as students informed test administrators that they enjoyed taking the test on computer and that they found the interactive questions interesting.
- Although PISA classified specific items as belonging to one of four knowledge systems that broadly overlap with those in the new Junior Certificate science syllabus, many questions sought information that did not reside in a specific content area. In this sense, students lacked an important cue that could have helped them identify relevant information with which to answer questions. Put another way, it was noted that 'the parameters for PISA science are less clear [than the Junior Certificate examination questions]'.

Overall, the reviewers' observations point to significant challenges confronting students taking the PISA 2015 computer-based test, especially those encountering interactive, simulation-based items for the first time, and those who may be challenged by having to process significant quantities of text and identify the specific information required to respond to a question. It is recognised that, in practice, these challenges interact with other factors such as previous experience with tasks similar to those presented in PISA, motivation to do well on PISA, and indeed, knowledge of science and knowledge of the scientific process. In 2018, it is planned to ask all students participating in PISA to indicate the effort they put into doing the test.

One of the observations provided by reviewers (i.e., students may write less in text boxes than on paper) may be possible to investigate further, by reviewing text length on open-ended constructed response items administered on paper in earlier PISA cycles, and on computer in 2015. Similarly, the hypothesis that students may have marked just one multiple-choice response when asked to mark one or more responses could be investigated by examining patterns of answers on pre-2015 paper-based items and their computer-based counterparts in 2015.

3.5. Summary and Conclusion

In this chapter, research on mode effects was examined. Previous research (e.g., Wang et al., 2007, 2008) reports that computer-based and paper-based tests administered to primary and post-primary students are psychometrically equivalent. Others, however, point to aspects of tests that can give rise to differential performance across modes, including longer passages in reading and graphical questions in mathematics (Peak, 2005). Gender differences in favour of male students have also been noted, especially on cognitively more advanced tests. Research on differences across modes arising from differential exposure to computers was also noted, with Zhang et al. (2016) reporting that access to a computer at home can explain variation in performance, even after accounting for socioeconomic status and other relevant variables. However, Zhang et al. offered the intriguing finding that differences on paper-based tests can often be explained by the same factors that explain variation on computer-based tests, suggesting administration mode may not be the main underlying factor explaining performance.

In line with the focus on science in PISA 2015, the outcomes of a study conducted in 2005 to examine the feasibility of implementing a computer-based test of science in an international large-scale study were reviewed. The CBAS Field Trial, in which Ireland was one of 12 participating countries, found that computer-based assessment (of science) was feasible in a study like PISA. Almost 90% of students in the Field Trial reported that they enjoyed doing the computer-based test, with more females that males reporting that they would take CBAS for fun. It was found that boys outperformed girls on the computer-based test and that this did not vary by country, while there no significant difference between genders across countries on the paper-based test. Of the 116 CBAS Field Trial items, 25 exhibited differential item functioning, with 12 favouring females, and 13 favouring males.

Just three countries participated in CBAS in the 2006 PISA Main Study – Denmark, Iceland and Korea. That study concluded that there was no evidence in any of these countries to support the view that overall group performance was affected by the method of test presentation.

The outcomes of the PISA tests of computer based reading (2009 and 2012), computer-based mathematics (2012) and computer-based problem solving (2012) were reviewed. While performance on average across OECD countries was about the same on the print- and computer-based tests of reading literacy in 2012 (when a larger number of countries participated in the digital reading assessment), there were some large within-country differences between modes, with, for example, Poland achieving a mean score on digital reading that was some 41 points lower than on digital reading. In contrast, on average, students in Ireland performed at about the same level on PISA 2012 digital and print reading.

Differences between countries were weaker on computer-based mathematics and problem solving in 2012 than on computer-based reading. However, in Ireland, students did significantly less well on computer-based mathematics than on paper-based mathematics, and achieved mean scores on both computer-based tests that were not significantly different from the corresponding OECD country average scores. It was hypothesised that a combination of factors may account for the performance of students in Ireland on the computer-based measures, including lack of familiarity with computer-based learning (including computer-based assessment) and weaknesses in general approaches to problem solving, especially among higher-achieving students.

It was observed that, in 2012, while the average gender difference in favour of female students on digital reading across OECD countries was smaller than for print reading, in Ireland the difference was marginally greater. In Ireland and on average across OECD countries, the gender difference on computer-based mathematics was marginally (but not significantly) greater than on print-based mathematics. On average across OECD countries, there was a significant difference of 6.6 points in favour of male students on computer-based problem solving. In Ireland, there was a non-significant difference of 5.3 points in favour of male students.

A mode study, conducted as part of the PISA 2015 Field Trial (administered in most countries including Ireland in spring 2014) confirmed the feasibility of implementing computer-based testing in PISA, and also concluded that performance on computer-based tests could be linked to earlier scales developed by PISA following administration of paper-based tests (reading in 2000, mathematics in 2003 and science in 2006). The Field Trial, in which Ireland participated, also provided the OECD and its contractors with an opportunity to examine changes to the model for scaling PISA data and for dealing with not reached items. A significant outcome of the Field Trial was that, within each domain, there was a set of items for which item invariance among item parameters did not hold. The Field trial did not look at country-by-mode interactions as samples were not always representative, and numbers of participants did not allow for strong inferences to be made. Analyses conducted by the Educational

Research Centre did find a small difference in favour of performance on paper-based items, over the same items when delivered by computer, especially for reading literacy.

The chapter concluded with a description of a review of PISA 2015 computer-based items conducted by science experts on the National PISA Advisory Committee and by staff at the Educational Research Centre. The review identified a range of factors that could have impacted on the performance of students in Ireland and in other countries that could account for the mode effect observed on some items. Among the issues identified by the review group were issues with the layout of PISA science items, problems with the flow of wording within units and items and difficulties for students in identifying how much information to provide in open-ended items where answers must be typed into text boxes. The challenge posted by interactive items where students must run virtual experiments, interpret the outcomes by drawing on their scientific knowledge and then provide the specific information required by the PISA questions was noted.

Chapter 4: Performance on PISA 2015 Science

Science is the major assessment domain in PISA 2015. The concept of science literacy addresses the ability of students to engage with, and to understand, the issues and ideas of science and technology (OECD, 2016b). In PISA 2015, science literacy encompasses not only what students know, but also how they use what they know and how they apply this knowledge creatively in everyday situations (OECD, 2016b). Science literacy, therefore, requires key competencies in science, as well as knowledge of the content and methods of science, and of the major fields of science – physics, chemistry, biology and Earth and Space Sciences. In Chapter 1, the framework for assessing science literacy was described in detail. In this chapter, the performance of students in Ireland on PISA science literacy (henceforth, science) is examined, and is compared to the performance of students in other participating countries, economies and regions.

Students' performance on PISA science is firstly described by comparing mean achievement scores on the overall science scale and by examining variation in performance using percentile markers. Next, performance in science is described in terms of the percentages of students achieving science proficiency levels. Thirdly, students' science achievement is presented across subscales reflecting the key science competencies (*Explain Phenomena Scientifically*, *Evaluate and Design Scientific Enquiry*, and *Interpret Data and Evidence Scientifically*), the necessary science knowledge (*Content*, and *Procedural and Epistemic*) and the major science knowledge systems (*Physical*, *Living,* and *Earth and Space*). Finally, gender differences in achievement in PISA science are discussed.

Mean scores on overall science are presented for all participating countries and economies and are ordered from highest to lowest. All other comparisons are made using a selection of participating countries, and one region (Northern Ireland). Included are the highest performing country (Singapore), the highest performing EU country (Estonia), the five highest performing OCED countries (Japan, Estonia, Finland, Canada, and Korea), the two countries with scores closest to Ireland (one above and one below) in PISA 2012 science (Australia and the Netherlands), other countries of general interest or relevance (France, Sweden, United Kingdom, and United States), and Northern Ireland. Selected countries are presented together in tables in descending order by mean score on the overall science scale. Singapore and Northern Ireland are presented below a broken line, as Singapore is a non-OECD country and Northern Ireland is a region of the United Kingdom.

Additional data tables related to this chapter can be accessed in the PISA 2015 E-Appendix at www.erc.ie/pisa.

4.1. Overall Performance on Science

With a mean score of 502.6 on the overall PISA science literacy scale, Ireland's performance is significantly above the performance of OECD countries on average (493.2) (Table 4.1). Ireland's performance ranks 13th among all OECD countries, and 19th among the 70 PISA-participating countries and economies. With a 95% confidence interval applied, Ireland's true rank in science lies between 11th and 18th among OECD countries, and between 17th and 24th among all participating countries and economies (see E-Appendix Table A4.1).

Ireland significantly outperforms 45 PISA countries/economies in science (17 OECD countries) and is one of 24 PISA countries/economies performing significantly above the OECD average in science (Table 4.1). Ireland's mean score in science does not differ significantly from the mean scores of 10 countries (the United Kingdom, Germany, the Netherlands, Switzerland, Belgium, Denmark, Poland, Portugal, Norway, and the United States). Fourteen countries have significantly higher mean scores than Ireland, including 8 OECD countries.

The highest performing country/economy overall in science is Singapore, which, with a mean score of 555.6, significantly outperforms all other countries/economies (Table 4.1). The next highest performer is Japan (also the highest performing OECD country) with a mean score of 538.4, followed by Estonia (also the highest ranked EU country) with a mean score of 534.2. Students in Northern Ireland (not in Table 4.1) achieved a mean score of 500.0 (SE=2.8), which is significantly above the OECD average, and not significantly different from Ireland's mean score.

Table 4.1. Mean country/economy scores, standard deviations and standard errors for the overall science scale, and positions relative to the OECD and Irish means, for all participating countries/economies

	Mean	SE	SD	SE	IRL		Mean	SE	SD	SE	IRL
Singapore	555.6	(1.20)	103.6	(0.90)	▲	*Croatia*	475.4	(2.45)	89.3	(1.25)	▼
Japan	538.4	(2.97)	93.5	(1.65)	▲	Argentina Cities	475.2	(6.28)	85.8	(2.72)	▼
Estonia	534.2	(2.09)	88.9	(1.10)	▲	Iceland	473.2	(1.68)	91.2	(1.15)	▼
Chinese Taipei	532.3	(2.69)	99.6	(1.92)	▲	Israel	466.6	(3.44)	106.4	(1.63)	▼
Finland	530.7	(2.39)	96.2	(1.31)	▲	*Malta*	464.8	(1.64)	117.6	(1.51)	▼
Macao (China)	528.5	(1.06)	81.4	(0.96)	▲	Slovak Republic	460.8	(2.59)	98.9	(1.53)	▼
Canada	527.7	(2.08)	92.4	(0.88)	▲	Greece	454.8	(3.92)	91.9	(1.84)	▼
Viet Nam	524.6	(3.91)	76.6	(2.34)	▲	Chile	447.0	(2.38)	86.0	(1.34)	▼
Hong Kong (China)	523.3	(2.55)	80.6	(1.41)	▲	*Bulgaria*	445.8	(4.35)	101.5	(2.10)	▼
B-S-J-G (China)	517.8	(4.64)	103.4	(2.47)	▲	*UAE*	436.7	(2.42)	99.1	(1.06)	▼
Korea	515.8	(3.13)	95.2	(1.47)	▲	*Uruguay*	435.4	(2.20)	86.5	(1.26)	▼
New Zealand	513.3	(2.38)	104.1	(1.43)	▲	*Romania*	434.9	(3.23)	79.1	(1.72)	▼
Slovenia	512.9	(1.32)	95.2	(1.08)	▲	*Cyprus*	432.6	(1.38)	92.8	(1.16)	▼
Australia	510.0	(1.54)	102.3	(0.92)	▲	*Moldova*	428.0	(1.97)	86.0	(1.35)	▼
United Kingdom	509.2	(2.56)	99.7	(1.02)	O	*Albania*	427.2	(3.28)	78.5	(1.45)	▼
Germany	509.1	(2.70)	99.3	(1.48)	O	Turkey	425.5	(3.93)	79.3	(1.89)	▼
Netherlands	508.6	(2.26)	100.9	(1.49)	O	*Trinidad + Tobago*	424.6	(1.41)	93.8	(1.10)	▼
Switzerland	505.5	(2.90)	99.5	(1.55)	O	*Thailand*	421.3	(2.83)	78.5	(1.58)	▼
Ireland	502.6	(2.39)	88.9	(1.33)		*Costa Rica*	419.6	(2.07)	70.0	(1.21)	▼
Belgium	502.0	(2.29)	100.2	(1.24)	O	*Qatar*	417.6	(1.00)	98.7	(0.74)	▼
Denmark	501.9	(2.38)	90.3	(1.14)	O	*Colombia*	415.7	(2.36)	80.4	(1.29)	▼
Poland	501.4	(2.51)	90.8	(1.34)	O	Mexico	415.7	(2.13)	71.4	(1.09)	▼
Portugal	501.1	(2.43)	91.8	(1.08)	O	*Montenegro*	411.3	(1.03)	85.3	(0.88)	▼
Norway	498.5	(2.26)	96.2	(1.30)	O	*Georgia*	411.1	(2.42)	90.6	(1.31)	▼
United States	496.2	(3.18)	98.6	(1.40)	O	*Jordan*	408.7	(2.67)	84.4	(1.59)	▼
Austria	495.0	(2.44)	97.3	(1.31)	▼	*Indonesia*	403.1	(2.57)	68.4	(1.64)	▼
France	495.0	(2.06)	102.0	(1.45)	▼	*Brazil*	400.7	(2.30)	89.2	(1.27)	▼
Sweden	493.4	(3.60)	102.5	(1.37)	▼	*Peru*	396.7	(2.36)	76.7	(1.41)	▼
Czech Republic	492.8	(2.27)	95.3	(1.45)	▼	*Lebanon*	386.5	(3.40)	90.4	(1.76)	▼
Spain	492.8	(2.07)	88.0	(1.08)	▼	*Tunisia*	386.4	(2.10)	64.9	(1.57)	▼
Latvia	490.2	(1.56)	82.2	(1.06)	▼	*FYR of Macedonia*	383.7	(1.25)	84.8	(1.29)	▼
Russian Federation	486.6	(2.91)	82.4	(1.05)	▼	*Kosovo*	378.4	(1.70)	71.3	(1.11)	▼
Luxembourg	482.8	(1.12)	100.4	(1.08)	▼	*Algeria*	375.7	(2.64)	69.3	(1.51)	▼
Italy	480.5	(2.52)	91.4	(1.35)	▼	*Dominican Rep.*	331.6	(2.58)	72.5	(1.80)	▼
Hungary	476.7	(2.42)	96.3	(1.58)	▼	OECD Average	493.2	(0.43)	94.4	(0.23)	▼
Lithuania	475.4	(2.65)	90.9	(1.41)	▼	EU Average	489.1	(0.70)	95.0	(0.33)	▼
						EU Total	494.8	(0.75)	97.8	(0.42)	▼

(dark grey)	Significantly above the OECD average	▲	Significantly higher than Ireland
(white)	At OECD average	O	Not significantly different to Ireland
(light blue)	Significantly below the OECD average	▼	Significantly lower than Ireland

OECD countries are in regular font, partner countries/economies are in italics. Argentina, Malaysia and Kazakhstan are omitted, as coverage is too small to ensure comparability (OECD, 2016b). Data for four Argentinian cities are provided.

4.2. Variation in Performance on Overall Science

Using key percentile markers, it is possible to examine the spread of science achievement scores within a country, economy, or region. This can be achieved by finding the difference between the 5th and 95th percentiles, which also gives the range into which 90% of students' scores fall (Table 4.2).

The range of scores in science in Ireland is 291.9 and this is considerably lower than the OECD average of 308.7 points. Indeed, among the selected comparison countries, Ireland has the lowest variability in science scores, followed very closely by Northern Ireland (292.0) and Estonia (293.2). Ireland displays less variability in science achievement than the Netherlands, Germany, the United Kingdom and the United States, even though Ireland's overall performance in science does not differ significantly from these comparison countries (Table 4.1).

Ireland's score of 386.7 at the 10th percentile, is the 7th highest among the selected comparison countries (Table 4.2). At this percentile, Ireland's performance is considerably stronger than the performance of the OECD countries on average (367.7). At the 90th percentile, Ireland performs less well than the comparison countries, but its mean score of 617.6 is similar to the OECD average of 614.8. In Northern Ireland, students at the 90th percentile have a score of 618.2, and hence perform very similarly to students in the rest of Ireland.

Among the selected countries, the greatest variability in achievement on overall science literacy is observed in France (360.0), followed by Sweden (348.5) and the United States (345.9). Estonia has the highest-performing students at the 10th percentile, with a score (415.6) that is some 47.9 points above the OECD average. Singapore has the highest performing students at the 90th percentile with a score of 683.3, some 68.5 points above the corresponding OECD average.

Table 4.2. Range, and scores with standard errors at key percentile markers on the overall science scale in Ireland, in selected comparison countries, and on average across OECD and EU countries

		5th		10th		25th		75th		90th		95th	
	Range	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Japan	308.0	375.0	(5.28)	411.9	(4.43)	474.9	(3.91)	604.7	(3.19)	655.0	(3.99)	683.0	(4.74)
Estonia	293.2	383.8	(4.31)	415.6	(3.31)	472.9	(2.70)	596.9	(2.70)	648.2	(2.88)	677.0	(3.75)
Finland	316.4	364.5	(4.63)	401.6	(4.16)	466.0	(3.51)	598.9	(2.53)	651.2	(2.69)	680.9	(3.45)
Canada	304.5	369.4	(3.25)	403.7	(2.92)	465.4	(2.53)	592.6	(2.24)	643.9	(2.57)	673.9	(2.71)
Korea	312.6	352.1	(4.67)	388.1	(4.46)	451.1	(3.76)	583.9	(3.26)	636.2	(3.67)	664.7	(3.92)
N. Zealand	341.0	340.7	(3.50)	374.5	(3.84)	438.6	(3.80)	587.7	(2.84)	647.4	(3.53)	681.7	(3.79)
Australia	336.1	336.4	(2.59)	371.8	(2.48)	438.2	(2.18)	583.0	(1.93)	639.3	(2.24)	672.5	(2.78)
UK	335.6	344.9	(2.86)	376.7	(3.21)	437.6	(2.95)	580.6	(3.07)	637.8	(3.17)	670.5	(3.47)
Germany	326.3	342.4	(4.43)	376.0	(4.33)	439.4	(3.57)	579.9	(2.80)	636.4	(2.89)	668.7	(3.76)
Netherlands	327.3	341.0	(4.05)	371.9	(4.30)	434.1	(3.93)	583.3	(2.51)	638.2	(2.93)	668.3	(3.63)
Ireland	291.9	356.1	(5.01)	386.7	(3.91)	441.5	(3.24)	564.6	(2.53)	617.6	(2.53)	648.0	(3.21)
US	345.9	336.4	(4.13)	367.6	(3.89)	424.9	(3.68)	567.5	(3.89)	625.5	(3.89)	658.3	(4.86)
France	360.0	308.1	(5.37)	347.4	(5.12)	419.3	(4.96)	570.9	(4.83)	633.3	(5.55)	668.1	(5.85)
Sweden	348.5	307.9	(4.94)	345.3	(4.76)	416.3	(3.68)	570.7	(3.31)	625.9	(3.71)	656.4	(4.38)
OECD Average	308.7	336.4	(0.69)	367.7	(0.63)	426.1	(0.57)	561.0	(0.50)	614.8	(0.55)	645.1	(0.63)
EU Average	310.7	332.6	(1.09)	363.3	(1.04)	421.3	(0.93)	557.1	(0.89)	611.8	(0.86)	643.3	(1.05)
EU Total	319.1	332.7	(1.33)	364.5	(1.11)	425.0	(1.03)	565.2	(0.83)	620.4	(0.97)	651.8	(1.10)
Singapore	339.7	372.8	(3.66)	411.9	(2.78)	485.3	(2.20)	631.0	(1.80)	683.3	(2.25)	712.5	(3.06)
N. Ireland	292.0	352.3	(4.80)	379.5	(4.50)	434.3	(4.00)	565.1	(4.00)	618.2	(4.50)	644.3	(4.60)

The range is defined as the difference between the 5th and 95th percentiles.

4.3. Performance on Science Proficiency Levels

PISA 2015 describes seven levels of proficiency for the overall science literacy scale (Table 4.3). Proficiency levels define the skills, abilities and competencies that students scoring within specific ranges are likely to demonstrate. For example, students at Proficiency Level 2 are those who score between 410 and 484 points in PISA science. At Level 2, students are beginning to display the key competencies that will enable them to participate effectively and productively in life situations related to science and technology and in future education in these fields (OECD, 2016a). As such, Level 2 is considered the baseline level of science proficiency necessary for students to engage reflectively with science and technology issues (OECD, 2016b). Proficiency Levels 1a and 1b describe what is needed to reach the baseline proficiency level. Students at Level 1b, the lowest proficiency level, display the skills necessary to correctly answer only the very easiest of science items. PISA does not define the skills and abilities of those whose scores fall below Level 1b (i.e., below 261 score points). The highest proficiency level is Level 6 (708 points and above) and students at this level demonstrate the competencies necessary to answer the most complex science literacy items.

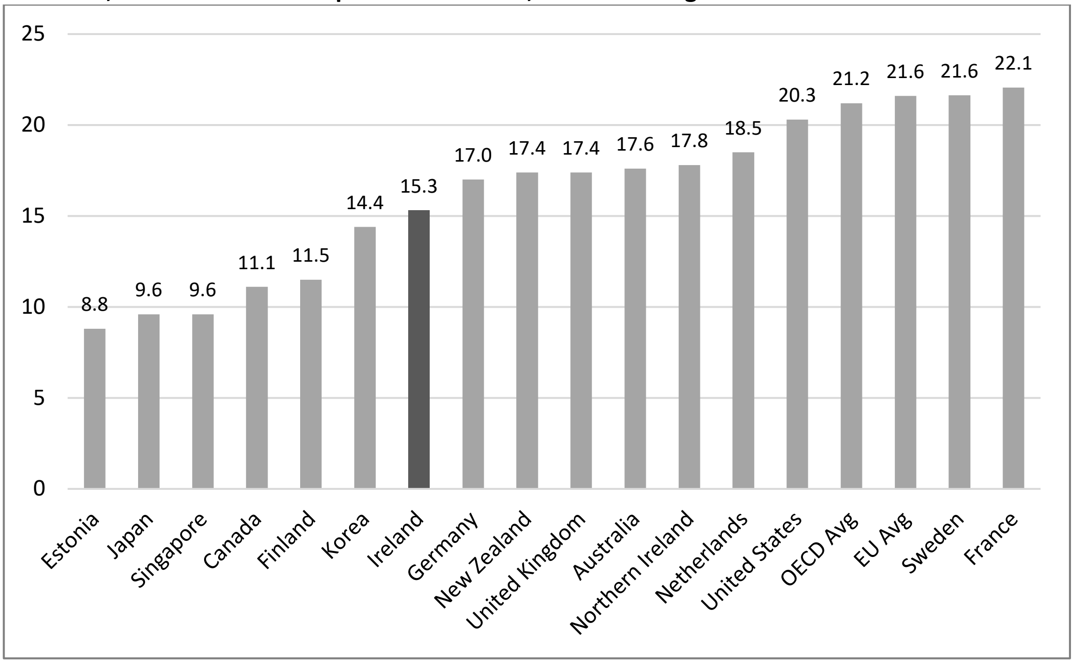
Table 4.3. Summary description of the seven levels of proficiency in science in PISA 2015, and percentages of students achieving each level in Ireland, on average across OECD and EU countries

Level (Cut-point)	Students at this level are capable of:	Ireland		OECD Avg		EU Avg	
		%	**SE**	**%**	**SE**	**%**	**SE**
6 (708 and above)	At Level 6, students can draw on a range of interrelated scientific ideas and concepts from the physical, life and earth and space sciences and use content, procedural and epistemic knowledge in order to offer explanatory hypotheses of novel scientific phenomena, events and processes or to make predictions. In interpreting data and evidence, they are able to discriminate between relevant and irrelevant information and can draw on knowledge external to the normal school curriculum. They can distinguish between arguments that are based on scientific evidence and theory and those based on other considerations. Level 6 students can evaluate competing designs of complex experiments, field studies or simulations and justify their choices.	0.8	(0.2)	1.1	(0.0)	1.0	(0.1)
5 (633 to less than 708)	At Level 5, students can use abstract scientific ideas or concepts to explain unfamiliar and more complex phenomena, events and processes involving multiple causal links. They are able to apply more sophisticated epistemic knowledge to evaluate alternative experimental designs and justify their choices and use theoretical knowledge to interpret information or make predictions. Level 5 students can evaluate ways of exploring a given question scientifically and identify limitations in interpretations of data sets including sources and the effects of uncertainty in scientific data.	6.3	(0.4)	6.7	(0.1)	6.4	(0.1)
4 (559 to less than 633)	At Level 4, students can use more complex or more abstract content knowledge, which is either provided or recalled, to construct explanations of more complex or less familiar events and processes. They can conduct experiments involving two or more independent variables in a constrained context. They are able to justify an experimental design, drawing on elements of procedural and epistemic knowledge. Level 4 students can interpret data drawn from a moderately complex data set or less familiar context, draw appropriate conclusions that go beyond the data and provide justifications for their choices.	20.1	(0.8)	19.0	(0.1)	18.7	(0.2)
3 (484 to less than 559)	At Level 3, students can draw upon moderately complex content knowledge to identify or construct explanations of familiar phenomena. In less familiar or more complex situations, they can construct explanations with relevant cueing or support. They can draw on elements of procedural or epistemic knowledge to carry out a simple experiment in a constrained context. Level 3 students are able to distinguish between scientific and non-scientific issues and identify the evidence supporting a scientific claim.	31.1	(0.9)	27.2	(0.1)	27.3	(0.2)
2 (410 to less than 484)	At Level 2, students are able to draw on everyday content knowledge and basic procedural knowledge to identify an appropriate scientific explanation, interpret data, and identify the question being addressed in a simple experimental design. They can use basic or everyday scientific knowledge to identify a valid conclusion from a simple data set. Level 2 students demonstrate basic epistemic knowledge by being able to identify questions that can be investigated scientifically.	26.4	(0.9)	24.8	(0.1)	25.1	(0.2)
1a (335 to less than 410)	At Level 1a, students are able to use basic or everyday content and procedural knowledge to recognise or identify explanations of simple scientific phenomenon. With support, they can undertake structured scientific enquiries with no more than two variables. They are able to identify simple causal or correlational relationships and interpret graphical and visual data that require a low level of cognitive demand. Level 1a students can select the best scientific explanation for given data in familiar personal, local and global contexts.	12.4	(0.8)	15.7	(0.1)	15.8	(0.2)
1b (261 to less than 335)	At Level 1b, students can use basic or everyday scientific knowledge to recognise aspects of familiar or simple phenomenon. They are able to identify simple patterns in data, recognise basic scientific terms and follow explicit instructions to carry out a scientific procedure.	2.7	(0.4)	4.9	(0.1)	5.1	(0.1)
Below 1b (less than 26l)	PISA 2015 does not define the competencies and skills of those scoring below Level 1b.	0.3	(0.1)	0.6	(0.0)	0.7	(0.0)

Adapted from OECD (2016b). Figures for EU countries on average were derived from data in OECD (2016b). Due to rounding, figures may differ slightly from those presented elsewhere in this report.

In Ireland, 15.3% of students perform below Level 2 proficiency on overall science (Figure 4.1). This compares to 21.2% of students on average across OECD countries. Hence, in Ireland, a greater proportion of students achieves baseline science proficiency (84.7%) than in OECD countries on average (78.8%). Countries with 17-20% performing below Level 2 include New Zealand, the United Kingdom, Australia, and Northern Ireland, while over 20% in the United States, Sweden and France perform below Level 2 (see Figure 4.1). In five countries, fewer than 12% of students perform below Level 2 (Estonia, Japan, Singapore, Canada, and Finland). Over 90% of students in Japan and Singapore meet the baseline proficiency level, while Estonia has the greatest proportion, at 91.2%.

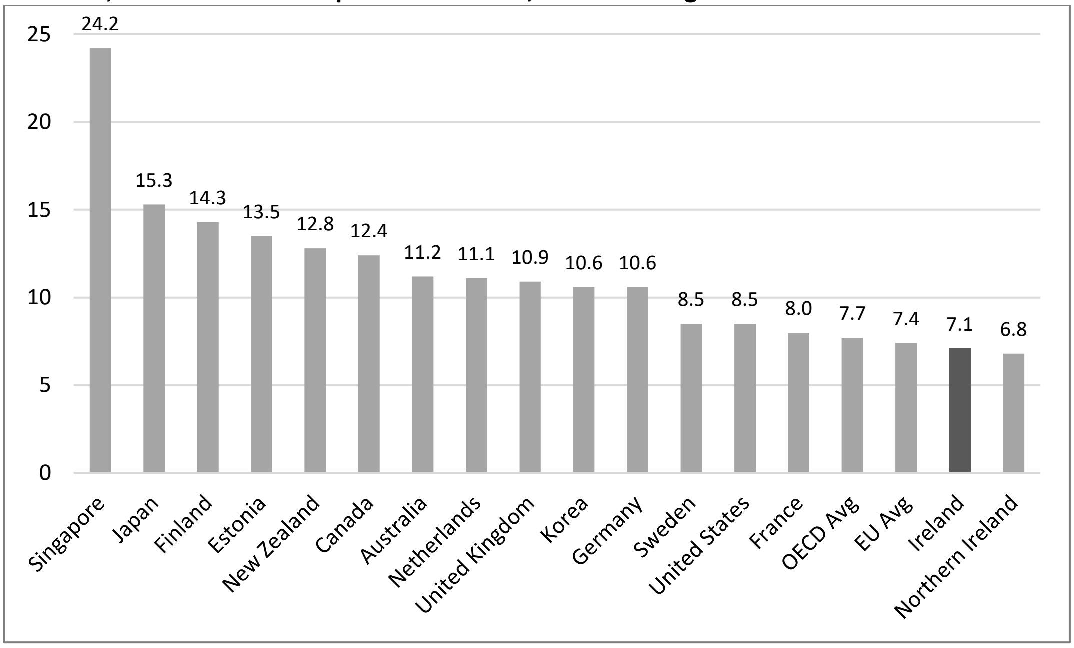
Figure 4.1. Percentages of students performing below Proficiency Level 2 on the overall science scale in Ireland, in the selected comparison countries, and on average across OECD and EU countries



See E-Appendix Table A4.2 for the percentages of students at each proficiency level on overall science, in Ireland, in selected comparison countries, and on average across OECD and EU countries.

The top performers in science attain Proficiency Level 5 or higher. In Ireland, 7.1% of students perform at or above Level 5 in science, a similar proportion as performs at this level across OECD countries (7.7%) on average (Figure 4.2). Northern Ireland (6.8%) and France (8.0%) also have similar proportions of top performers to Ireland. Most of the other comparison countries have greater proportions of students at Level 5 and above. Singapore has the highest percentage, with almost one quarter of students (24.2%) performing at Level 5 or above, and 5.6% performing at Level 6 (E-Appendix Table A4.2). In comparison, 0.8% of students in Ireland, 0.5% in Northern Ireland, and 1.1% across the OECD on average, perform at Level 6 (E-Appendix Table A4.2).

Figure 4.2. Percentages of students performing at or above Proficiency Level 5 on the overall science scale in Ireland, in the selected comparison countries, and on average across OECD and EU countries



See E-Appendix Table A4.2 for the percentages of students at each proficiency level on overall science, in Ireland, in selected comparison countries, and on average across OECD and EU countries.

4.4. Performance on Science Subscales

As noted in the description of the PISA science framework in Chapter 1, performance on PISA science can be examined with reference to different dimensions of science including science competencies, types of scientific knowledge, and content knowledge systems. Eight subscales were developed across three broad areas: science competencies (3 subscales), science knowledge (2) and science content systems (3).

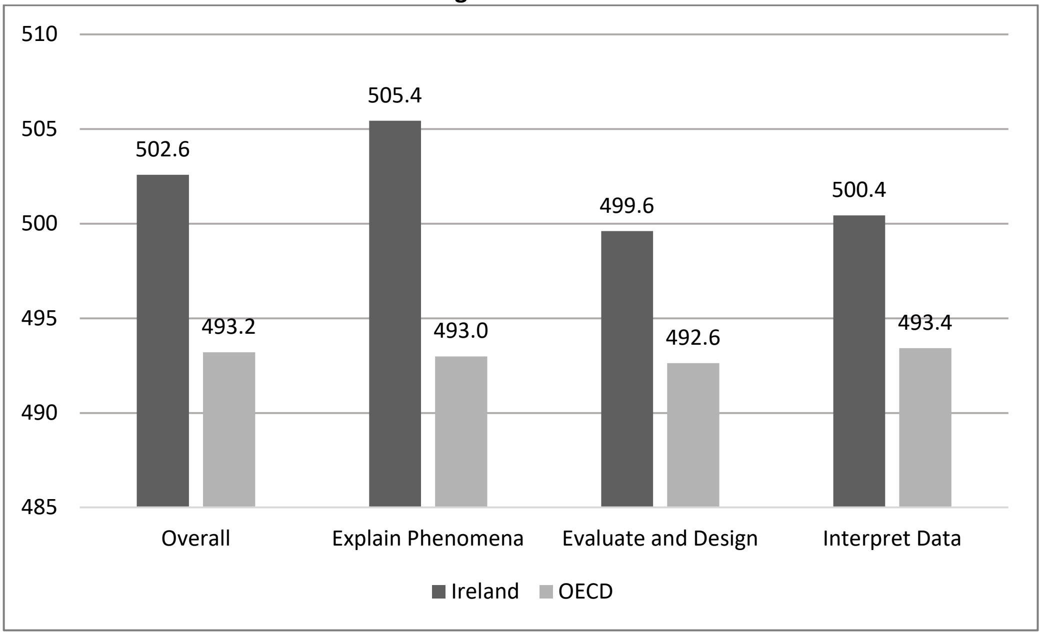
Here, a brief overview of performance on the subscales is presented, with performance in Ireland compared with average performance across OECD countries on each scale. More detailed information, including the percentages of students at key percentile markers and proficiency levels on the subscales, can be found in OECD (2016b).

It should be noted that the OECD revised the science subscale scores in November, 2016, and it is not clear at the time of writing if further modifications will be made. Hence, care needs to be exercised in interpreting the outcomes reported below.

Central to the PISA 2015 definition of science literacy are three key competencies – the abilities to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically. The first competency, Explain Phenomena*,* involves recognising, offering and evaluating explanations for a range of natural and technological phenomena. This competency is assessed with 89 items comprising almost half (48%) of all science items. The second competency, Evaluate and Design, is based on the ability to describe and appraise scientific enquiries and propose ways of addressing questions scientifically. This competency is assessed with 39 items, comprising 21% of all science items. The third competency, Interpret Data, involves analysing and evaluating scientific information, claims and arguments in a variety of representations and drawing appropriate conclusions. This competency is assessed with 56 items, equating to 30% of all science items. Examples of the skills and abilities relating to each competency are provided in Chapter 1.

Figure 4.3 presents mean scores on the overall science scale and the three science competency subscales for Ireland and on average across OECD countries. Ireland's mean score is significantly higher than the corresponding OECD average on each science competency subscale, with a difference of 7.0 points on both Evaluate and Design and Interpret Data, and a difference of 12.4 points on Explain Phenomena. Hence, Explain Phenomena can be considered a relative strength, compared with Evaluate and Design and Interpret Data. According to the OECD (2016b, Table I.2.13), the 5.8 points difference in Ireland in favour of Explain Phenomena over Evaluate and Design, and the 5.0 points difference in favour of Explain Phenomena over Interpret Data are both statistically significant, while the difference between Evaluate and Design and Interpret Data (-0.84) is not. On average across OECD countries, only the 0.79 points difference in favour of Interpret Data over Evaluate and Design is statistically significant.

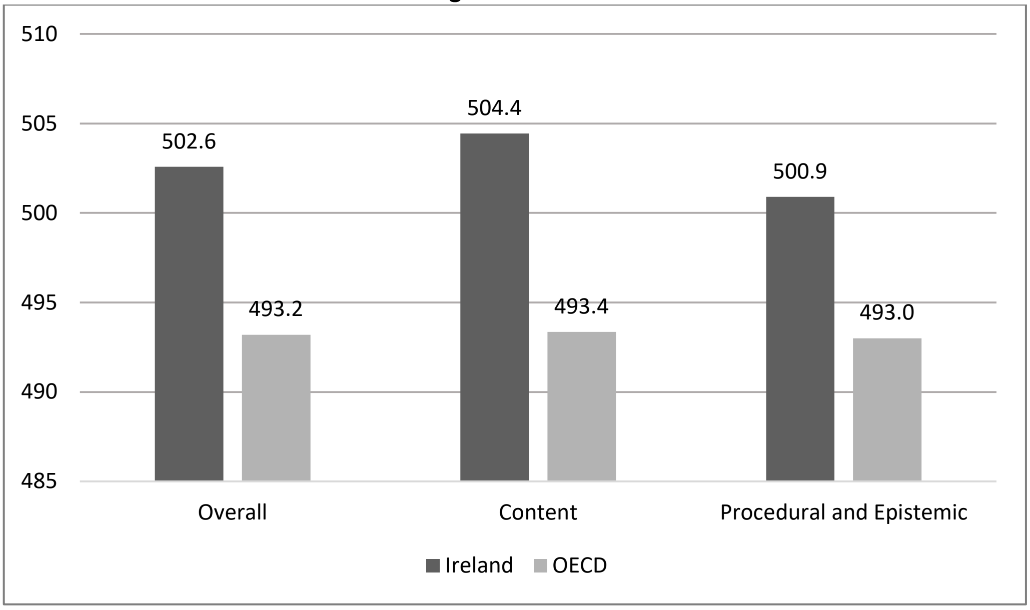
Figure 4.3. Mean scores on the overall science scale and the three science competency subscales, in Ireland and on average across OECD countries



In PISA 2015, science literacy is also defined in terms of requisite science knowledge. The three key science competencies require different forms of science knowledge. Firstly, science literacy requires Content Knowledge, or knowledge of theories, explanatory ideas, information and facts in science and technology. Secondly, science literacy requires Procedural Knowledge, or knowledge of how science content knowledge is produced. Thirdly, science literacy requires Epistemic Knowledge, or knowledge of the nature and origin of knowledge in science. In PISA 2015, science content knowledge is assessed with 98 items, comprising over half (53%) of all science items. Procedural and Epistemic Knowledge items are combined into one scale of 86 items accounting for 47% of all science items. Here, students' performance is reported in relation to the two science knowledge subscales: Content Knowledge and Procedural and Epistemic Knowledge.

Figure 4.4 presents mean scores on the overall science scale and the two science knowledge subscales in Ireland, and on average across OECD countries. Ireland scores significantly above the OECD average on the two science knowledge subscales, with differences of 11.0 points for Content Knowledge and 7.9 for Procedural and Epistemic Knowledge. According to the OECD (2016b, Table I.2.14), the 4.5 score point difference in Ireland on Content Knowledge, compared with Procedural and Epistemic Knowledge, is statistically significant. The corresponding average difference across OECD countries (0.34) is not statistically significant.

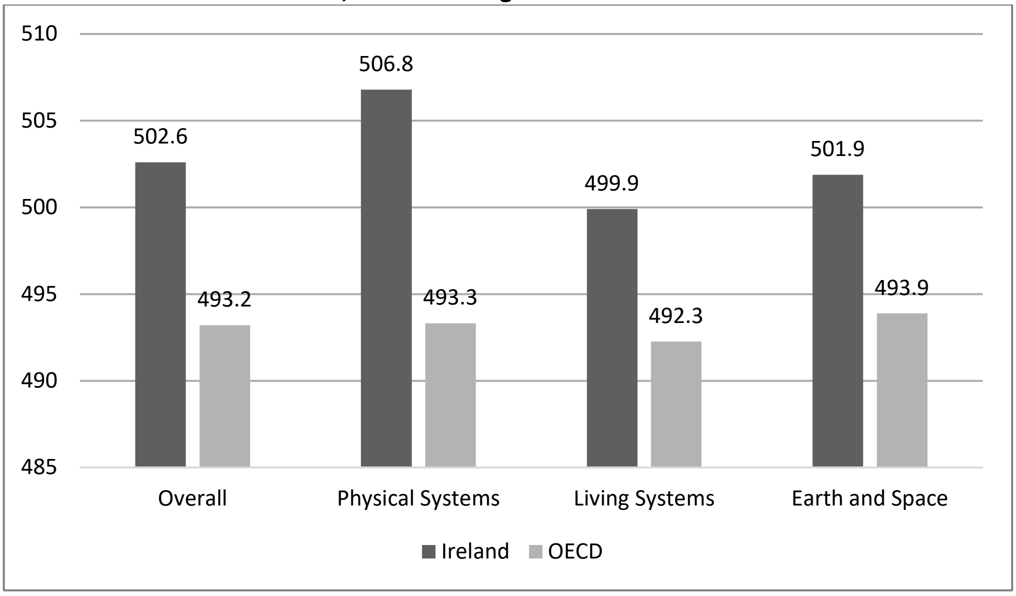
Figure 4.4. Mean scores on the overall science scale and the two science knowledge subscales, in Ireland, and on average across OECD countries



In PISA 2015, science content knowledge is classified according to the major fields of science, which are Physical Systems (physics and chemistry), Living Systems (biology) and Earth and Space Sciences (OECD, 2016b). Knowledge of Physical Systems requires, for example, knowledge of chemical reactions, motion and forces, energy and its transformation, and interactions between energy and matter. Knowledge of Living Systems refers to knowledge of, for example, the cell and its structures, human biology, ecosystems and the biosphere. Knowledge of Earth and Space Sciences involves knowledge of earth systems (e.g., the atmosphere), the solar system, and the history and scale of the universe, for example. Among the PISA science items are 61 items (33%) assessing Physical Systems, 74 items (40%) assess content knowledge of Living Systems, and 49 items (27%) assess content knowledge of Earth and Space sciences. Here, students' performance on the three science content knowledge systems subscales (Physical Systems, Living Systems, and Earth and Space) is described.

Figure 4.5 presents mean scores on the overall science scale and the three science content systems subscales in Ireland, and on average across OECD countries. Ireland scores significantly above the OECD average on the three content systems subscales with differences of 13.5 points for Physical Systems, 7.6 points for Living Systems, and 8.0 points for Earth and Space. According to the OECD (2016b, Table I.12.15), students in Ireland had a significantly higher means score, by 6.9 points, on Physical Systems, compared with Living Systems, and by 4.9 points on Physical Systems, compared with Earth and Space Systems. The difference of 2.0 score points in favour of Earth and Space Systems over Living Systems is not statistically significant. On average across OECD countries, performance on Physical Systems is significantly higher than on Living Systems, by 0.89 score points, and performance on Earth and Space Systems is significantly higher than on Living Systems, by 1.6 score points. As in Ireland, the difference between Earth and Space Systems and Living Systems (0.8 points) is not statistically significant.

Figure 4.5. Mean scores on the overall science scale and the three science content systems subscales, in Ireland, and on average across OECD countries



4.5. Gender Differences in Science Performance

Male students significantly outperform female students on the overall science literacy scale in Ireland, and across OECD countries on average (Table 4.4). The score difference between males and females in Ireland is 11 points compared to the OECD average of 4 points. Males also score significantly higher than females on overall science in the United States, Germany and Japan, with differences of 7 points, 11 points and 14 points respectively. In Finland, in contrast, females significantly outperform males by a difference of 19 score points. Females also outperform males in Korea (10 points) and Sweden (5 points), but the differences are not significant. Males score higher than females in the remaining countries (Estonia, Canada, New Zealand, Australia, United Kingdom, the Netherlands, France, and Singapore), but not significantly. In Northern Ireland, the difference of three points between males and females is similar to the OECD average difference, but is not significant.

In Ireland, male students perform significantly above the OECD average for males on overall science, and significantly above male students in France and Sweden. However, male students in Singapore, Japan, Estonia, Finland, and Canada significantly outperform male students in Ireland on the overall science scale.

Female students in Ireland score significantly above the OECD average for females. Female students in Ireland also score higher than female students in the United States, France, and Sweden, but not significantly. Mean scores of female students in Singapore, Japan, Estonia, Finland, Canada, Korea, New Zealand, the United Kingdom and the Netherlands are significantly higher than mean score of female students in Ireland.

Table 4.4. Gender differences on the overall science scale in Ireland, in selected comparison countries, and on average across OECD and EU countries

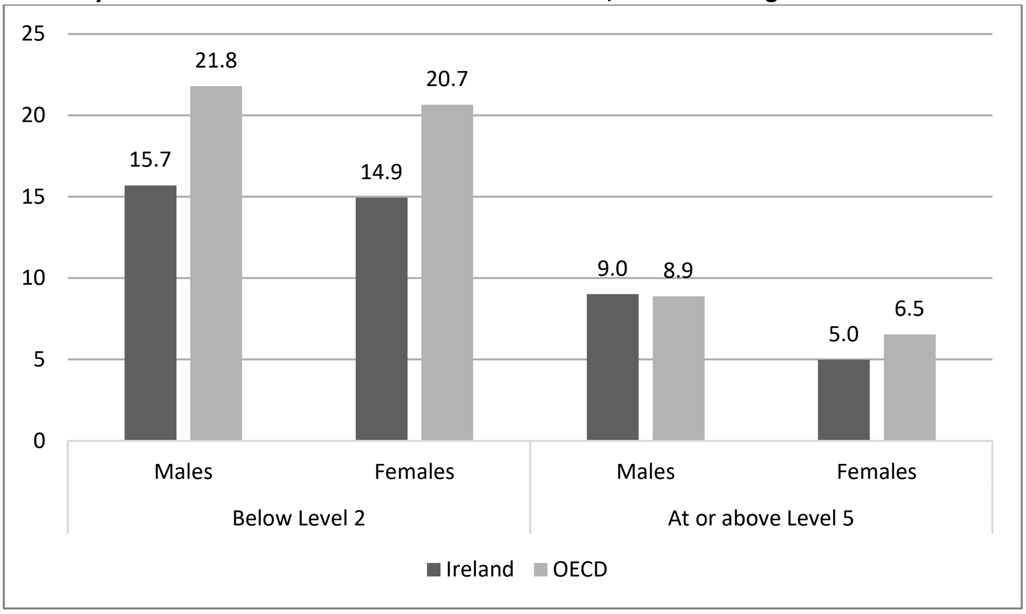
	Males		Females		Gender differences (M-F)	
	Mean	SE	Mean	SE	Score diff.	SED
Japan	545.1	(4.14)	531.5	(2.88)	**13.6**	(3.93)
Estonia	535.8	(2.72)	532.5	(2.26)	3.3	(2.76)
Finland	521.5	(2.72)	540.5	(2.64)	**-19.0**	(2.45)
Canada	528.3	(2.52)	527.2	(2.25)	1.1	(2.36)
Korea	511.2	(4.59)	520.8	(3.27)	-9.6	(5.01)
New Zealand	515.8	(3.20)	510.7	(2.74)	5.1	(3.59)
Australia	511.0	(2.12)	508.9	(1.72)	2.1	(2.34)
United Kingdom	509.6	(2.89)	508.8	(3.29)	0.7	(3.47)
Germany	514.3	(3.22)	503.8	(2.77)	**10.5**	(2.59)
Netherlands	510.6	(2.91)	506.5	(2.46)	4.1	(2.95)
Ireland	507.7	(3.16)	497.2	(2.62)	**10.5**	(3.21)
United States	499.6	(3.67)	492.9	(3.40)	**6.8**	(3.07)
France	495.9	(2.70)	494.0	(2.66)	1.9	(3.43)
Sweden	491.2	(4.12)	495.7	(3.70)	-4.6	(3.13)
OECD Average	495.0	(0.54)	491.4	(0.49)	**3.5**	(0.58)
EU Average	488.3	(0.59)	487.3	(0.54)	1.0	(0.62)
Singapore	558.7	(1.76)	552.3	(1.72)	6.4	(2.52)
Northern Ireland	501.5	(3.87)	498.7	(3.22)	2.8	(4.45)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

Figure 4.6 presents the percentages of male and female students performing below Proficiency Level 2 and at or above Proficiency Level 5 on the overall science scale in Ireland and on average across OECD countries. In Ireland, a slightly greater percentage of males (15.7%) than females (14.9%) performs at or below Level 2 proficiency in overall science. Similarly, across OECD countries on average, a slightly greater percentage of males (21.8%) performs below Level 2 compared to females (20.7%). The percentage of males performing below Level 2 in Ireland (15.7%) is considerably smaller than the corresponding OECD average (21.8%). Similarly, the percentage of females performing below Level 2 in Ireland (14.9%) is considerably smaller than the OECD average (20.7%).

A greater percentage of males (9.0%) than females (5.0%) performs at or above Level 5 on overall science in Ireland (Figure 4.6). Similarly, across OECD countries on average, a greater percentage of males (8.9%) than females (6.5%) performs at Level 5 or higher. In Ireland, a similar percentage of male students (9.0%) performs at or above Level 5 as performs at this level across OECD countries on average (8.9%). Also, similar percentages of female students perform at Level 5 or higher in Ireland (5.0%) and in OECD countries on average (6.5%).

Figure 4.6. Percentages of male and female students achieving below Proficiency Level 2 and at or above Proficiency Level 5 on the overall science scale in Ireland, and on average across OECD countries



Male students in Ireland outperform female students on two of three science competency subscales (OECD, 2016b, Tables I.2.16d, I.2.17d and I.2.18d), with a significant difference of 17.2 points on Explain Phenomena, a non-significant difference of 1.5 points on Evaluating and Designing, and a significant 7.3 score points difference on Interpreting Data and Evidence. On average across OECD countries, males have a significantly higher mean score (by 12.1 points) on Explain Phenomena. Differences on Evaluate and Design (1.5 points in favour of males) and Interpret Data (1.3 points in favour of females) are not statistically significant.

On the science knowledge subscales, there is a significant difference of 17.5 score points in favour of males on Content Knowledge, and a non-significant difference of 3.8 points in favour of males on Procedural and Epistemic Knowledge (OECD, 2016b, Tables I.2.19d and I.2.20d). On average across OECD countries, there is a significant difference of 11.9 points in favour of males on Content Knowledge and a non-significant difference of 3.4 points in favour of females on Procedural and Epistemic Knowledge.

There are significant differences in favour of male students in Ireland on all three science knowledge systems: 11.1 points on Physical Systems, 9.0 points on Life Systems and 10.8 points on Earth and Space Systems (OECD, 2016b, Tables I.2.21d, I.2.22d, and I.2.23d). On average across OECD countries, male students significantly outperform females by 8.6 points on Physical Systems, and by 3.7 points on Earth and Space Systems. Females have a non-significant advantage of 0.4 points on Living Systems.

4.6. Summary and Conclusion

Ireland's performance on PISA 2015 science was described in detail in this chapter. In summary, Ireland has a mean score of 502.6 on overall science, which is significantly higher than the OECD average (493.2), and significantly higher than the mean scores of 45 PISA-participating countries/economies. The mean score of students in Ireland on PISA science does not differ significantly from the mean scores of students in the United Kingdom, Germany, the Netherlands, Switzerland, Belgium, Denmark, Poland, Portugal, Norway, the United States, and Northern Ireland.

Compared to most comparison countries and the OECD average, the gap between higher and lower performers in Ireland is small. Indeed, Ireland's lower performers in science (students scoring at the 10th percentile) have a higher score than their counterparts in most comparison countries, while Ireland's stronger performers (students at the 90th percentile) have a lower score. Furthermore, while Ireland has fewer students performing below Proficiency Level 2 (15.3%) than the majority of comparison countries, Ireland has a smaller proportion of top performers in science (i.e., those scoring at or above Level 5) (7.1%) than all of its comparators, with the exception of Northern Ireland. The percentage of top performers in science in Ireland (7.1%) does not differ significantly from the OECD (7.7%) average.

In PISA 2015, key competencies and knowledge for science literacy are assessed using eight overlapping subscales derived from the overall science scale. Ireland's mean score is significantly higher than the corresponding OECD average score all three science competence subscales, with a relative strength on Explain Phenomena, compared with Evaluate and Design and Interpret Data. Ireland's mean scores on the Content Knowledge and Procedural and Epistemic Knowledge subscales are also higher than the corresponding OECD average scores (by 11.0 and 7.9 points respectively). Students in Ireland also perform above the corresponding OECD averages on Physical Systems, Living Systems and Earth and Space Systems, with performance on Physical Systems an area of relative strength.

On PISA 2015 overall science, male students in Ireland significantly outperform female students by 10.5 score points, while on average across OECD countries, the difference in favour of male students was a significant 3.5 score points. Male students also perform significantly higher than females in the United States (by 6.8 points), Germany (by 10.5), and Japan (by 13.6). In Finland, female students have a mean score that is significantly higher than males by 19 score points.

While similar percentages of male (15.7%) and female (14.9%) students in Ireland perform below Level 2 on the PISA overall science scale, more males (9.0%) than females (5.0%) perform at or above Level 5. Similarly, on average across OECD countries, similar percentages of males (21.8%) and females (20.7%) perform below Level 2, while more males (8.9%) than females (6.5%) perform at or above Level 5. Moreover, the OECD average proportions below Level 2 are higher than in Ireland, while they are broadly similar to Ireland's at or above Level 5.

In line with their higher overall performance on science, male students in Ireland significantly outperform their female counterparts on two of three science competencies (Explain Phenomena and Interpreting Data and Evidence), on one of two knowledge subscales (Content Knowledge), and on all three science knowledge systems (Physical Systems, Life Systems and Earth and Space Systems). The largest differences are on Explain Phenomena Scientifically (17.2 points), Content Knowledge (17.5) and Physical Systems (11.1). Average differences across OECD countries also tend to favour male students, though not to the same extent as in Ireland. On average across OECD countries, differences between competence, knowledge and systems subscales tend to be small, though, as in Ireland, students perform marginally better on Physical Systems compared with other content systems.

Chapter 5: Performance on PISA 2015 Reading Literacy and Mathematics

This chapter looks at performance in the two minor domains assessed in PISA 2015 – reading literacy and mathematics. It describes overall performance, performance at key percentile markers, performance by proficiency level, and gender differences. Results are examined with reference to a group of comparison countries/economies which were selected on the same basis as in the previous chapter on science[30], but with reference to performance in reading literacy and mathematics. In the relevant tables, the countries/economies are arranged in descending order of mean score, with the exception of the two entities, Northern Ireland (region) and Singapore (non-OECD country), which are below the dotted line. As reading and mathematics are minor domains, performance is reported with reference to the overall scale scores only. The frameworks for assessing reading and mathematics were discussed in Chapter 1, and the transition from paper to computer-based testing in 2015 was noted. Supplementary tables are provided in the E-Appendix at www.erc.ie/pisa. Trends in reading literacy and mathematics achievement over time are examined in Chapter 8.

5.1. Overall Performance on Reading Literacy

Reading literacy was assessed as a minor domain in PISA 2015. This means that only overall performance is reported on. Scores are not reported for subscales, even though the full reading literacy framework (see Chapter 1) was taken into account in compiling clusters of items for the test. Also, as noted in Chapter 1, the reading literacy items in PISA 2015 comprise a subset (88) of the items that were administered on paper in PISA 2009, when reading literacy was a major assessment domain. In 2015, these items were administered on computer for the first time.

Ireland's mean score of 520.8 on the reading scale is significantly higher than the OECD average of 492.5 (Table 5.1). Ireland is ranked 3rd out of 35 OECD countries and 5th out of all 70 participating countries/economies. Applying a 95% confidence interval, which takes account of measurement and sampling error, Ireland's true rank in reading among the OECD countries is between 2nd and 6th and between 4th and 8th among all participating countries/economies.

Singapore significantly outperforms every other participating country/economy in reading, with a mean score of 535.1 and is also the only country that significantly outperforms Ireland. Ireland's mean score does not differ from that of six countries/economies (Hong Kong-China, Canada, Finland, Estonia, Korea and Japan). The remaining 63 countries/economies, including 29 OECD countries, perform significantly less well than Ireland. The mean reading score for Northern Ireland is 497.0 (SE = 4.57; SD = 83.8). This is significantly below the mean score for Ireland, but is not significantly different from the OECD average.

Table 5.1 also shows the standard deviation for all countries/economies. Ireland's standard deviation for reading is 86.2. This is smaller than the OECD average of 96.0, indicating a narrower spread of reading achievement in Ireland than across OECD countries.

[30] For each domain, the top scoring country/economy, the top five OECD countries, 6 countries of interest (UK, US, France, N Zealand, Germany, Sweden), Northern Ireland, and Ireland (if not already included) were selected.

Table 5.1. Mean scores, standard deviations and standard errors for all participating countries/economies on the PISA 2015 reading literacy scale and positions relative to the OECD and Irish means, for all participating countries/economies

	Mean	SE	SD	SE	IRL		Mean	SE	SD	SE	IRL
Singapore	535.1	(1.63)	98.7	(1.06)	▲	Israel	479.0	(3.78)	113.1	(1.97)	▼
Hong Kong	526.7	(2.69)	85.8	(1.45)	O	*Argentina-Cities*	475.3	(7.19)	90.5	(3.38)	▼
Canada	526.7	(2.30)	92.8	(1.33)	O	*Lithuania*	472.4	(2.74)	94.4	(1.55)	▼
Finland	526.4	(2.55)	93.9	(1.53)	O	Hungary	469.5	(2.66)	97.0	(1.67)	▼
Ireland	520.8	(2.47)	86.2	(1.47)		Greece	467.0	(4.34)	98.2	(2.40)	▼
Estonia	519.1	(2.22)	87.5	(1.22)	O	Chile	458.6	(2.58)	88.1	(1.74)	▼
Korea	517.4	(3.50)	97.0	(1.73)	O	Slovak Republic	452.5	(2.83)	104.2	(1.75)	▼
Japan	516.0	(3.20)	92.4	(1.83)	O	*Malta*	446.7	(1.78)	120.6	(1.46)	▼
Norway	513.2	(2.51)	98.8	(1.69)	▼	*Cyprus*[1]	442.8	(1.65)	102.3	(1.27)	▼
New Zealand	509.3	(2.40)	105.0	(1.68)	▼	*Uruguay*	436.6	(2.55)	96.6	(1.60)	▼
Germany	509.1	(3.02)	100.1	(1.62)	▼	*Romania*	433.6	(4.07)	95.1	(2.12)	▼
Macao (China)	508.7	(1.25)	82.1	(1.07)	▼	*UAE*	433.5	(2.87)	105.7	(1.39)	▼
Poland	505.7	(2.48)	89.6	(1.30)	▼	*Bulgaria*	431.7	(5.00)	114.6	(2.60)	▼
Slovenia	505.2	(1.47)	91.8	(1.29)	▼	Turkey	428.3	(3.96)	82.4	(2.00)	▼
Netherlands	503.0	(2.41)	101.0	(1.65)	▼	*Costa Rica*	427.5	(2.63)	79.2	(1.55)	▼
Australia	502.9	(1.69)	102.7	(1.12)	▼	*Trinidad- Tob.*	427.3	(1.49)	104.1	(1.34)	▼
Sweden	500.2	(3.48)	101.8	(1.47)	▼	*Montenegro*	426.9	(1.58)	94.1	(1.20)	▼
Denmark	499.8	(2.54)	87.3	(1.16)	▼	*Colombia*	424.9	(2.94)	89.8	(1.53)	▼
France	499.3	(2.51)	112.0	(2.02)	▼	Mexico	423.3	(2.58)	78.0	(1.47)	▼
Belgium	498.5	(2.42)	100.2	(1.52)	▼	*Moldova*	*416.2*	*(2.52)*	*97.8*	*(1.48)*	▼
Portugal	498.1	(2.69)	92.0	(1.14)	▼	*Thailand*	*409.1*	*(3.35)*	*79.8*	*(1.69)*	▼
UK	498.0	(2.77)	96.7	(1.09)	▼	*Jordan*	*408.1*	*(2.93)*	*94.1*	*(1.78)*	▼
Chinese Taipei	497.1	(2.50)	93.2	(1.66)	▼	*Brazil*	*407.3*	*(2.75)*	*100.2*	*(1.54)*	▼
United States	496.9	(3.41)	99.8	(1.58)	▼	*Albania*	*405.3*	*(4.13)*	*96.6*	*(1.85)*	▼
Spain	495.6	(2.36)	87.3	(1.40)	▼	*Qatar*	*401.9*	*(1.02)*	*110.6*	*(0.97)*	▼
Russian Fed.	494.6	(3.08)	87.4	(1.39)	▼	*Georgia*	*401.3*	*(2.96)*	*103.6*	*(1.81)*	▼
B-S-J-G (China)	493.9	(5.13)	108.9	(2.90)	▼	*Peru*	*397.5*	*(2.89)*	*89.1*	*(1.60)*	▼
Switzerland	492.2	(3.03)	97.9	(1.69)	▼	*Indonesia*	*397.3*	*(2.87)*	*76.0*	*(1.77)*	▼
Latvia	487.8	(1.80)	84.8	(1.48)	▼	*Tunisia*	*361.1*	*(3.06)*	*81.6*	*(1.91)*	▼
Czech Republic	487.3	(2.60)	100.5	(1.74)	▼	*Dominican Rep.*	*357.7*	*(3.05)*	*84.9*	*(1.94)*	▼
Croatia	486.9	(2.68)	90.7	(1.56)	▼	*FYR Macedonia*	*351.7*	*(1.41)*	*99.2*	*(1.24)*	▼
Viet Nam	486.8	(3.73)	72.6	(2.03)	▼	*Algeria*	*349.9*	*(3.00)*	*72.7*	*(1.56)*	▼
Austria	484.9	(2.84)	101.1	(1.54)	▼	*Kosovo*	*347.1*	*(1.57)*	*78.3*	*(1.10)*	▼
Italy	484.8	(2.68)	93.8	(1.62)	▼	*Lebanon*	*346.5*	*(4.41)*	*115.5*	*(2.61)*	▼
Iceland	481.5	(1.98)	99.4	(1.66)	▼	OECD Average	492.5	(0.46)	96.0	(0.27)	▼
Luxembourg	481.4	(1.44)	106.6	(0.98)	▼	EU Average	486.0	(0.52)	97.5	(0.30)	▼
						EU Total	494.5	(0.87)	100.2	(0.52)	▼

■	Significantly above OECD average	▲	Significantly higher than Ireland
□	At OECD average	O	Not significantly different from Ireland
▒	Significantly below OECD average	▼	Significantly lower than Ireland

OECD countries are in regular font, partner countries/economies are in italics. Argentina, Malaysia and Kazakhstan are omitted, as coverage is too small to ensure comparability (OECD, 2016b). Data for four Argentinian cities are provided.

5.2. Variation in Performance on Reading Literacy

Table 5.2 presents the scores and standard errors at each of six key percentile markers for Ireland, for 11 comparison countries and Northern Ireland, and on average across OECD and EU countries. The range in reading achievement scores in Ireland between the 5th and 95th percentiles is 283.6 score points, which is significantly smaller than the OECD average range of 315.4 points (Table 5.2). Other countries with a similar range to Ireland include Estonia (290.2 points) and Northern Ireland (276.2 points).

At each key percentile marker, Ireland's score on reading is higher than the corresponding OECD average score, with a difference of 46.8 points at the 5th percentile and a difference of 15.1 at the 95th percentile (Table 5.2). The score for students at the 10th percentile in Ireland (406.4) is significantly higher than the corresponding OECD average (363.7). There is no significant difference at the 10th percentile between the scores of students in Ireland and in Canada, Finland, Estonia and Singapore. Lower-performing students in the remaining countries perform significantly less well than their counterparts in Ireland.

Higher performing students (i.e., those at the 90th percentile) in Ireland (628.6) have a significantly higher score than students on average across OECD countries (612.7). Higher performing students in Ireland also significantly outperform their counterparts in Northern Ireland (604.8). However, they perform significantly less well than students in Singapore (657.3), Canada (641.9), Finland (639.9), New Zealand (642.6), and France (636.9). The remaining comparison countries/economies are not significantly different to Ireland at the 90th percentile marker.

Table 5.2. Range, and mean scores and standard errors at key percentile markers on the reading literacy scale in Ireland, in selected comparison countries, and on average across OECD and EU countries

		5th		10th		25th		75th		90th		95th	
	Range	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Canada	305.3	366.1	(4.27)	403.6	(3.58)	465.8	(2.76)	591.3	(2.41)	641.9	(2.71)	671.4	(2.75)
Finland	308.9	358.7	(5.42)	400.7	(4.71)	468.7	(3.68)	591.9	(2.67)	639.9	(2.65)	667.6	(3.81)
Ireland	283.6	373.0	(4.56)	406.4	(4.09)	463.5	(3.06)	581.7	(2.68)	628.6	(2.81)	656.7	(4.10)
Estonia	290.2	368.5	(4.20)	404.1	(4.03)	460.5	(2.76)	581.0	(2.57)	630.0	(2.93)	658.7	(3.20)
Korea	320.4	345.3	(7.28)	385.9	(5.56)	455.0	(4.45)	586.1	(3.89)	637.0	(4.33)	665.7	(4.08)
N. Zealand	346.9	326.9	(4.83)	368.3	(4.48)	438.6	(3.65)	584.2	(3.32)	642.6	(4.34)	673.8	(4.36)
Germany	329.8	334.2	(5.24)	375.2	(5.27)	442.2	(3.76)	580.6	(3.11)	633.6	(3.40)	664.0	(3.21)
Sweden	333.6	321.3	(6.03)	363.9	(4.62)	433.0	(4.40)	573.3	(3.84)	625.5	(3.62)	654.9	(4.43)
France	367.1	299.2	(6.63)	343.9	(5.68)	422.7	(3.72)	582.5	(3.07)	636.9	(2.98)	666.3	(3.56)
UK	317.2	336.3	(4.36)	371.8	(4.00)	431.9	(3.18)	565.5	(3.05)	621.2	(3.56)	653.5	(4.13)
US	328.9	325.6	(5.99)	364.1	(5.43)	429.8	(4.72)	567.6	(3.95)	623.5	(3.79)	654.5	(3.74)
OECD Average	315.4	326.2	(0.88)	363.7	(0.77)	428.0	(0.63)	561.3	(0.52)	612.7	(0.58)	641.6	(0.66)
EU Average	319.2	317.6	(0.97)	355.0	(0.86)	419.7	(0.73)	556.2	(0.59)	608.3	(0.64)	637.5	(0.74)
EU Total	328.8	320.6	(1.68)	360.2	(1.54)	427.3	(1.12)	566.1	(0.97)	619.3	(1.10)	649.4	(1.34)
Singapore	324.7	361.8	(4.44)	400.2	(3.67)	469.6	(2.58)	606.6	(1.98)	657.3	(2.60)	686.5	(3.29)
N. Ireland	276.2	355.8	(7.01)	385.0	(6.14)	439.5	(5.03)	557.0	(5.69)	604.8	(5.26)	632.0	(6.80)

5.3. Performance on Reading Proficiency Levels

To help interpret what students' scores mean in substantive terms, the OECD has divided the reading scale into seven levels of proficiency, with each level indicating the types of tasks the student would be capable of completing successfully. The most recent description of proficiency levels for reading is based on the PISA 2009 assessment, as this was the most recent cycle in which reading was a major assessment domain. The lowest level of proficiency for reading is Level 1b with a cut-point score of 262.04, then Level 1a (334.75) and Level 2 (407.47) up to Level 6 (698.32). A summary description of the seven proficiency levels is given in Table 5.3.

Table 5.3. Summary description of the seven levels of proficiency on the PISA 2015 reading literacy scale and percentages of students achieving each level, in Ireland and on average across OECD and EU countries

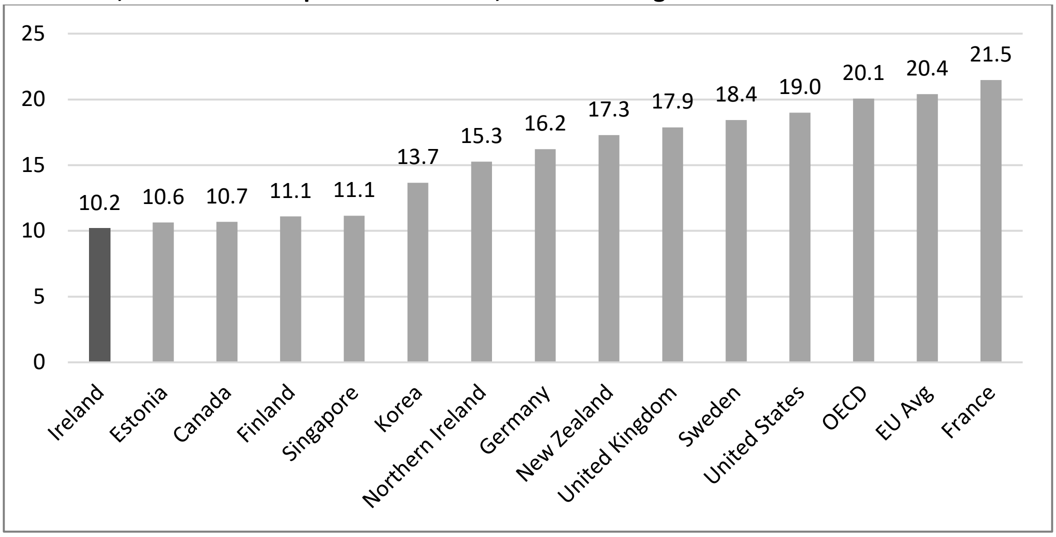
Level (Cut-point)	Students at this level are capable of:	Ireland		OECD Avg		EU Avg	
		%	SE	%	SE	%	SE
6 (698 and above)	Making multiple inferences, comparisons and contrasts that are both detailed and precise; demonstrating a full and detailed understanding of one or more texts that may involve integrating information from more than one text; dealing with unfamiliar ideas in the presence of prominent competing information, and generating abstract categories for interpretations; hypothesising about or critically evaluating a complex text on an unfamiliar topic, taking into account multiple criteria or perspectives, and applying sophisticated understanding from beyond the text; precision of analysis and fine attention to detail that is inconspicuous in the texts is needed.	1.3	(0.2)	1.1	(0.0)	0.9	(0.0)
5 (626 to less than 698)	Locating and organising several pieces of deeply embedded information, inferring which information in the text is relevant; engaging in critical evaluation or hypothesis formulation, drawing on specialised knowledge; a full and detailed understanding of a text whose content or form is unfamiliar. For all aspects of reading, tasks at this level typically involve dealing with concepts that are contrary to *expectations*.	9.4	(0.6)	7.2	(0.1)	6.5	(0.1)
4 (553 to less than 626)	Locating and organising several pieces of embedded information; interpreting the meaning of nuances of language in a section of text by taking into account the text as a whole; understanding and applying categories in an unfamiliar context; using formal or public knowledge to hypothesise about or critically evaluate a text. Readers must demonstrate an accurate understanding of long or complex texts whose content or form may be unfamiliar.	26.4	(0.8)	20.5	(0.1)	19.7	(0.2)
3 (480 to less than 553)	Locating, and in some cases recognising the relationship between several pieces of information that must meet multiple conditions; integrating several parts of a text in order to identify a main idea; understanding a relationship or construing the meaning of a word or phrase; taking into account many features in comparing, contrasting or categorising – often the required information is not prominent or there is much competing information; or there are other text obstacles, such as ideas that are contrary to expectations or negatively worded; making connections, comparisons and explanations, or evaluating a feature of the text to demonstrate a fine understanding of the text in relation to familiar, everyday knowledge. Other tasks do not require detailed text comprehension but require the reader to draw on less common knowledge.	31.8	(1.1)	27.9	(0.6)	27.6	(0.2)
2 (407 to less than 480)	Locating one or more pieces of information, which may need to be inferred and may need to meet several conditions; recognising the main idea in a text, understanding relationships, or construing meaning within a limited part of the text when the information is not prominent and the reader must make low level inferences; Tasks may involve comparisons or contrasts based on a single feature in the text; making a comparison or several connections between the text and outside knowledge, by drawing on personal experience and attitudes.	21.0	(0.9)	23.2	(0.2)	23.5	(0.2)
1a (335 to less than 407)	Locating one or more independent pieces of explicitly-stated information; recognising the main theme or author's purpose in a text about a familiar topic, or making a simple connection between information in the text and common, everyday knowledge; the required information in the text is prominent and there is little, if any, competing information. The reader is explicitly directed to consider relevant factors in the task and in the text.	8.3	(0.7)	13.6	(0.1)	14.1	(0.1)
1b (261 to less than 335)	Locating a single piece of explicitly stated information in a prominent position in a short, syntactically simple text with a familiar context and text type, such as a narrative or a simple list. The text typically provides support to the reader, such as repetition of information, pictures or familiar symbols. There is minimal competing information. In tasks requiring interpretation the reader may need to make simple connections between adjacent pieces of information.	1.7	(0.3)	5.2	(0.1)	6.0	(0.1)
Below 1B (less than 262)	There is insufficient information on which to base a description of the reading skills of these students	0.2	(0.1)	1.3	(0.0)	1.8	(0.1)

Adapted from OECD (2016b), Figure I.4.7.

The skills that students use to answer the PISA reading items reflect three processes: 'access and retrieve', 'integrate and interpret', and 'reflect and evaluate'. Students who do not display the skills required for Level 1b are identified as performing below Level 1b and the PISA assessment does not collect enough information to describe the skills of these students.

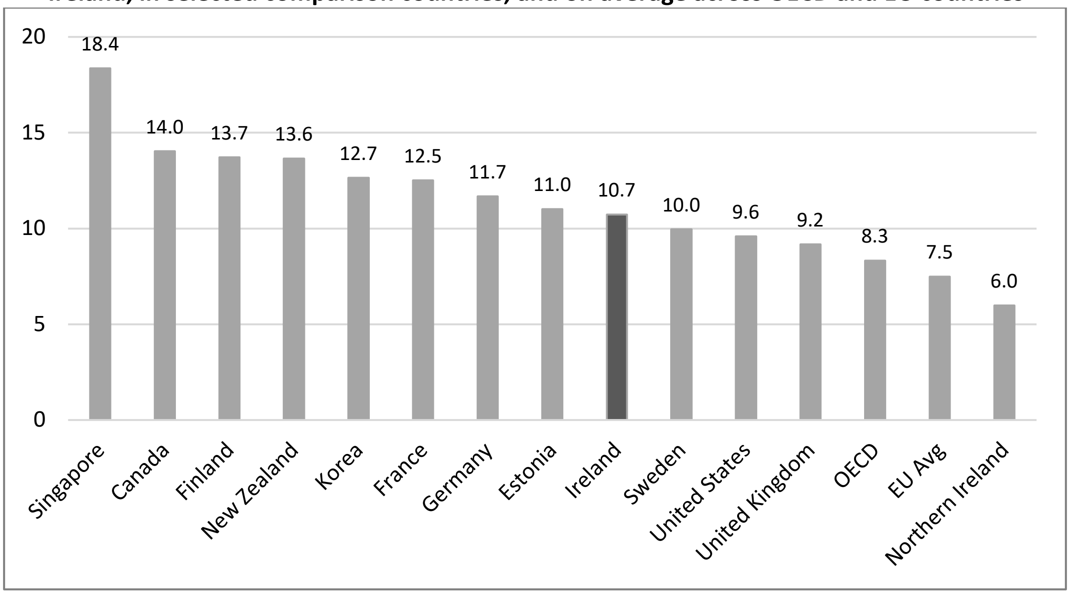
In Ireland, 10.2% of students perform at the lowest level of proficiency (i.e., below Level 2). This is about that same as in Estonia, Canada, Finland and Singapore (Figure 5.1). According to the OECD (2016b), these students have insufficient reading skills to deal with future needs in real life or in further learning. On average across OECD countries, 20.1% perform below Level 2, while in France, 21.5% do so.

Figure 5.1. Percentages of students performing below Level 2 on the PISA 2015 reading literacy scale in Ireland, in selected comparison countries, and on average across OECD and EU countries



In Ireland, 10.7% of students perform at the highest proficiency levels in reading (Levels 5-6 combined). This is about the same as in Germany, Estonia, Sweden and the United States, but below the proportions in Singapore, Canada, Finland or New Zealand. Ireland has more higher-achieving students than the average for OECD countries (8.3%) and Northern Ireland (6.0%).

Figure 5.2. Percentages of students performing at or above Level 5 on the PISA 2015 reading literacy scale in Ireland, in selected comparison countries, and on average across OECD and EU countries



5.4. Gender Differences on Reading Literacy

Female students in Ireland significantly outperform male students on PISA 2015 overall reading (Table 5.4). The difference, 12.0 score points, is among the lowest across comparison countries, and is also close to (and not significantly different from) the difference in Northern Ireland (14.2). On average across OECD countries, the gender difference in favour of female students is 26.9 points. Hence, the difference on average across OECD countries is over twice the size of the difference in Ireland. In Finland, the difference in favour of females is 46.5 points.

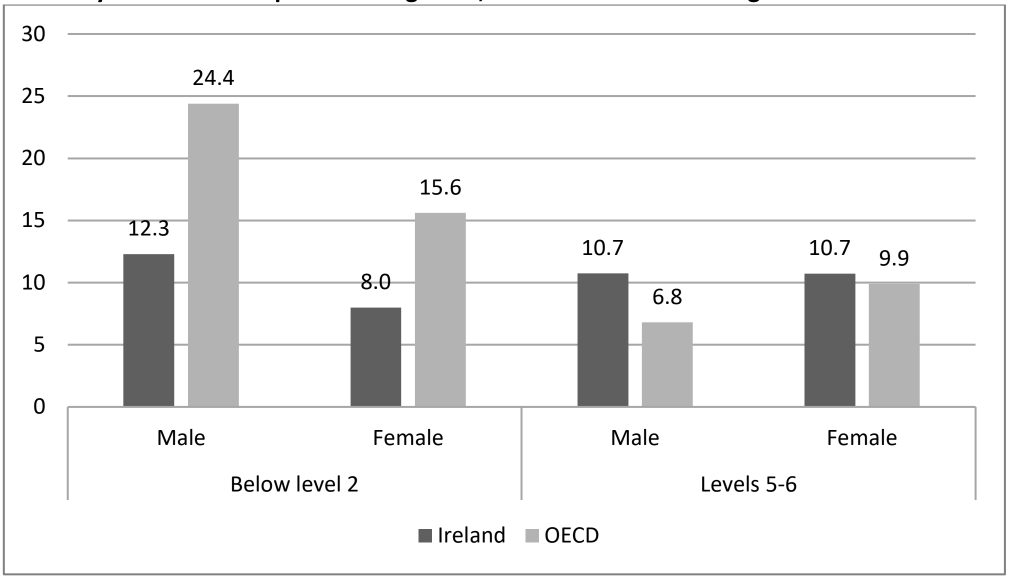
Table 5.4. Gender differences on the PISA 2015 reading literacy scale in Ireland, in selected comparison countries and on average across OECD and EU countries

	Males		Females		Difference (males-females)	
	Mean	SE	Mean	SE	Score diff.	SED
Canada	513.5	(2.55)	539.8	(2.49)	**-26.2**	(2.14)
Finland	504.0	(2.95)	550.5	(2.82)	**-46.5**	(2.92)
Ireland	515.0	(3.20)	526.9	(2.68)	**-12.0**	(3.38)
Estonia	505.5	(2.94)	533.4	(2.29)	**-27.9**	(2.95)
Korea	498.1	(4.77)	538.6	(4.01)	**-40.5**	(5.43)
New Zealand	493.2	(3.31)	525.5	(2.96)	**-32.3**	(4.07)
Germany	498.9	(3.68)	519.7	(3.08)	**-20.8**	(3.27)
Sweden	480.7	(4.06)	519.9	(3.48)	**-39.2**	(3.24)
France	484.6	(3.34)	513.8	(3.28)	**-29.1**	(4.37)
United Kingdom	487.2	(2.93)	509.1	(3.46)	**-21.9**	(3.26)
United States	486.9	(3.72)	507.0	(3.94)	**-20.1**	(3.56)
OECD Average	479.3	(0.58)	506.2	(0.54)	**-26.9**	(0.65)
EU Average	471.6	(0.64)	500.8	(0.60)	**-29.2**	(0.69)
Singapore	525.3	(1.87)	545.6	(2.31)	**-20.2**	(2.64)
Northern Ireland	489.9	(5.15)	504.1	(5.06)	**-14.2**	(4.52)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

Gender differences can also be interpreted with reference to proficiency levels. As per Figure 5.3, 12.3% of male students in Ireland performed below Level 2 on the PISA overall reading scale. This is well below the OECD average of 24.4%, indicating that there are relatively fewer male students performing poorly on reading literacy in Ireland. Similarly, 8.0% of female students in Ireland perform below Level 2, compared with 15.6% on average across OECD countries. Turning to higher performers, Figure 5.3 shows that 10.7% of male students in Ireland perform at Proficiency Levels 5-6, compared with an OECD average of 6.8%. On the other hand, the percentage of female students in Ireland performing at Levels 5-6 (10.7%) is only marginally higher than the corresponding OECD average (9.9%). This suggests that further improvements in reading literacy in Ireland could be achieved if more students, and female students in particular, perform at Levels 5-6.

Figure 5.3. Percentages of male and female students achieving below Proficiency Level 2 and at or above Proficiency Level 5 on the print reading scale, in Ireland and on average across OECD countries



See E-Appendix Table A5.2 for percentages of male and female students at each proficiency level on the reading scale, in Ireland and on average across OECD countries

5.5. Overall Performance on Mathematics

Like reading literacy, mathematics was assessed as a minor domain in PISA 2015. This means that only overall performance is reported on. Scores are not reported for subscales, even though the full mathematics framework (see Chapter 1) was taken into account in compiling clusters of items for the test. Also, as noted in Chapters 1, the mathematics items administered in PISA 2015 comprise a subset (69) of the items that had been administered on paper in PISA 2012, when mathematical literacy was a major assessment domain. In 2015, these items were administered on computer for the first time.

Ireland's mean score of 503.7 on the overall mathematics scale is significantly higher than the OECD average of 490.2 (Table 5.5). Ireland is ranked 13th out of 35 OECD countries and 18th out of all 70 participating countries/economies. Applying a 95% confidence interval, which takes account of measurement and sampling error, Ireland's true rank in mathematics among the OECD countries is between 10th and 14th and between 15th and 19th among all participating countries/economies.

As in reading literacy, Singapore significantly outperforms every other participating country/economy in mathematics, with a mean score of 564.2, and it is among 14 countries/economies that significantly outperform Ireland, including a number of countries that lag behind Ireland on reading literacy (Denmark, the Netherlands, Slovenia and Switzerland). Ireland's mean score does not differ from those of five countries/economies (Belgium, Germany, Poland, Norway and Austria). The remaining 51 countries/economies (19 of which are OECD countries, including Australia, the United Kingdom and the United States) perform significantly less well than Ireland. The mean mathematics score for Northern Ireland is 493.8 (SE = 4.59, SD = 77.5) and it is not significantly different from the mean score for Ireland, nor is it significantly different from the OECD average.

Table 5.5 also shows the standard deviation for each participating country/economy. Ireland's standard deviation for mathematics is 79.8, while the OECD average standard deviation is 89.5. This indicates a narrower spread of mathematics achievement in Ireland than on average across OECD countries. Indeed, the spread in Ireland is one of the lowest among OECD countries. Other countries with comparably low standard deviations include Denmark, Estonia, Finland and Norway. The standard deviation for Northern Ireland is 77.5 (SE = 1.95).

Table 5.5. Mean scores, standard deviations and standard errors for all participating countries/economies on the PISA 2015 mathematics scale and positions relative to the mean scores for Ireland and the average across OECD countries

	Mean	SE	SD	SE	IRL		Mean	SE	SD	SE	IRL
Singapore	564.2	(1.47)	95.4	(0.83)	▲	Hungary	476.8	(2.53)	93.8	(1.70)	▼
Hong Kong (C)	547.9	(2.98)	90.1	(1.51)	▲	Slovak Republic	475.2	(2.66)	95.4	(1.61)	▼
Macao (China)	543.8	(1.11)	79.9	(1.13)	▲	Israel	469.7	(3.63)	103.4	(2.16)	▼
Chinese Taipei	542.3	(3.03)	102.9	(1.95)	▲	United States	469.6	(3.17)	88.5	(1.52)	▼
Japan	532.4	(3.00)	88.2	(1.74)	▲	*Croatia*	464.0	(2.77)	88.3	(1.56)	▼
B-S-J-G (China)	531.3	(4.89)	106.0	(2.45)	▲	*Argentina-Cities*	456.3	(6.91)	88.5	(3.44)	▼
Korea	524.1	(3.71)	99.7	(1.77)	▲	Greece	453.6	(3.75)	89.4	(1.79)	▼
Switzerland	521.3	(2.92)	95.7	(1.58)	▲	*Romania*	444.0	(3.79)	86.3	(2.10)	▼
Estonia	519.5	(2.04)	80.4	(1.06)	▲	*Bulgaria*	441.2	(3.95)	97.2	(2.37)	▼
Canada	515.6	(2.31)	87.7	(1.05)	▲	*Cyprus*[1]	437.1	(1.72)	92.4	(1.06)	▼
Netherlands	512.3	(2.21)	91.5	(1.46)	▲	*UAE*	427.5	(2.41)	96.5	(1.29)	▼
Denmark	511.1	(2.17)	80.6	(1.22)	▲	Chile	422.7	(2.54)	85.4	(1.41)	▼
Finland	511.1	(2.31)	82.2	(1.26)	▲	Turkey	420.5	(4.13)	81.9	(2.35)	▼
Slovenia	509.9	(1.26)	87.8	(1.29)	▲	*Moldova*	419.7	(2.47)	90.1	(1.53)	▼
Belgium	507.0	(2.35)	97.4	(1.47)	O	*Uruguay*	418.0	(2.50)	86.6	(1.65)	▼
Germany	506.0	(2.89)	89.0	(1.39)	O	*Montenegro*	417.9	(1.46)	86.6	(1.35)	▼
Poland	504.5	(2.39)	87.6	(1.67)	O	*Trinidad-Tob.*	417.2	(1.41)	96.0	(1.19)	▼
Ireland	**503.7**	**(2.05)**	**79.8**	**(1.38)**		*Thailand*	415.5	(3.03)	81.5	(1.95)	▼
Norway	501.7	(2.23)	84.9	(1.10)	O	*Albania*	413.2	(3.45)	86.2	(1.62)	▼
Austria	496.7	(2.86)	95.1	(1.83)	O	Mexico	408.0	(2.24)	75.0	(1.28)	▼
New Zealand	495.2	(2.27)	92.1	(1.31)	▼	*Georgia*	403.8	(2.78)	93.9	(2.19)	▼
Viet Nam	494.5	(4.46)	83.7	(2.71)	▼	*Qatar*	402.4	(1.27)	98.8	(1.00)	▼
Russian Fed.	494.1	(3.11)	83.1	(1.32)	▼	*Costa Rica*	400.3	(2.47)	68.4	(1.43)	▼
Sweden	493.9	(3.17)	90.1	(1.74)	▼	*Lebanon*	396.2	(3.69)	101.1	(1.99)	▼
Australia	493.9	(1.61)	93.1	(1.23)	▼	*Colombia*	389.6	(2.29)	77.2	(1.35)	▼
France	492.9	(2.10)	95.2	(1.53)	▼	*Peru*	386.6	(2.71)	82.6	(1.37)	▼
United Kingd.	492.5	(2.50)	92.6	(1.36)	▼	*Indonesia*	386.1	(3.08)	79.8	(1.99)	▼
Czech Republic	492.3	(2.40)	90.7	(1.74)	▼	*Jordan*	380.3	(2.65)	85.8	(2.08)	▼
Portugal	491.6	(2.49)	95.7	(1.30)	▼	*Brazil*	377.1	(2.86)	89.2	(1.73)	▼
Italy	489.7	(2.85)	93.6	(1.67)	▼	*FYR Macedonia*	371.3	(1.28)	95.9	(1.60)	▼
Iceland	488.0	(1.99)	92.9	(1.33)	▼	*Tunisia*	366.8	(2.95)	84.2	(2.34)	▼
Spain	485.8	(2.15)	84.7	(1.27)	▼	*Kosovo*	361.5	(1.63)	75.3	(1.40)	▼
Luxembourg	485.8	(1.27)	93.6	(1.18)	▼	*Algeria*	359.6	(2.95)	71.1	(1.53)	▼
Latvia	482.3	(1.87)	77.5	(1.19)	▼	*Dominican Rep.*	327.7	(2.69)	68.5	(2.01)	▼
Malta	478.6	(1.72)	110.3	(1.38)	▼	OECD Average	490.2	(0.44)	89.5	(0.26)	▼
Lithuania	478.4	(2.33)	86.5	(1.39)	▼	EU Average	487.1	(0.48)	90.2	(0.29)	▼
						EU Total	492.6	(0.79)	92.2	(0.49)	▼

(dark shading)	Significantly above OECD average	▲	Significantly higher than Ireland
(no shading)	At OECD average	O	Not significantly different from Ireland
(light shading)	Significantly below OECD average	▼	Significantly lower than Ireland

OECD countries are in regular font, partner countries/economies are in italics. Argentina, Malaysia and Kazakhstan are omitted, as coverage is too small to ensure comparability (OECD, 2016b). Data for four Argentinian cities are provided.

5.6. Variation in Performance on Mathematics

Table 5.6 presents the scores and standard errors at each of six key percentile markers for Ireland, for 12 comparison countries and Northern Ireland, and on average across OECD and EU countries. The range in mathematics achievement scores in Ireland between the 5th and 95th percentiles is 261.9 score points, which is significantly smaller than the OECD average range of 293.3 points. Other countries with comparatively small differences between the 5th and 95th percentiles include Estonia (264.3 points), and Northern Ireland (253.2 points). The gaps between the highest and lowest performers in the remaining comparison countries/economies are greater than in Ireland.

Whereas the scores of students in Ireland at the 5th, 10th and 25th percentiles are greater than the corresponding OECD average scores, the scores of students in Ireland at the 75th, 90th and 95th percentiles are not significantly different. For example, the score of students in Ireland at the 10th percentile is 399.8, compared with 372.6 on average across OECD countries, whereas the score of students in Ireland at the 90th percentile is 606.1, and the corresponding OECD average is 604.6 (the difference is not significant). Ireland has higher scores than students in Germany, New Zealand and the United Kingdom at the 5th and 10th percentiles, but lower scores than students in these countries at the 90th and 95th percentiles. Finally, students in Singapore and Japan are ahead of students in Ireland at all six percentile scores in Table 5.5, while students in the US are behind students in Ireland at all six.

Table 5.6. Scores of students at key percentile markers on mathematics scale in Ireland, in selected comparison countries and on average across OECD and EU countries

		5th		10th		25th		75th		90th		95th	
	Range	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE	Score	SE
Japan	290.4	381.4	(5.56)	416.1	(4.42)	473.6	(3.52)	594.1	(3.47)	642.9	(4.20)	671.8	(5.42)
Korea	327.3	353.3	(5.94)	391.4	(5.45)	457.6	(4.47)	594.2	(4.17)	649.2	(4.33)	680.6	(4.82)
Switzerland	312.7	358.5	(5.08)	394.2	(4.41)	454.8	(3.92)	589.8	(3.44)	641.4	(3.39)	671.2	(3.87)
Estonia	264.3	385.9	(3.73)	414.7	(3.08)	463.5	(2.63)	575.8	(2.62)	623.5	(2.70)	650.2	(3.44)
Canada	288.6	368.5	(3.69)	400.3	(3.17)	455.7	(2.86)	576.6	(2.58)	627.3	(3.19)	657.1	(3.58)
Germany	293.1	356.4	(4.86)	389.3	(4.12)	445.2	(3.45)	568.0	(3.35)	619.6	(3.35)	649.5	(3.87)
Ireland	261.9	370.6	(4.40)	399.8	(3.80)	450.1	(2.73)	558.7	(2.21)	606.1	(2.59)	632.5	(2.71)
N. Zealand	303.5	342.3	(3.80)	374.6	(3.80)	430.6	(3.19)	560.0	(2.76)	613.1	(3.09)	645.8	(4.43)
Sweden	296.1	342.0	(4.96)	375.8	(4.41)	432.7	(3.81)	557.2	(3.95)	608.7	(3.94)	638.0	(4.73)
France	308.5	330.9	(4.51)	364.1	(3.92)	425.0	(3.25)	563.7	(2.62)	612.8	(2.71)	639.5	(3.30)
UK	303.1	337.4	(4.29)	370.9	(3.71)	429.8	(3.22)	556.5	(3.05)	610.0	(3.09)	640.5	(3.98)
US	289.8	323.5	(4.68)	354.9	(3.93)	408.1	(3.86)	531.8	(3.53)	584.5	(4.22)	613.3	(5.04)
OECD Average	293.3	340.5	(0.76)	372.6	(0.65)	428.5	(0.56)	553.3	(0.53)	604.6	(0.60)	633.8	(0.71)
EU Average	295.3	336.6	(0.86)	368.5	(0.74)	424.7	(0.63)	550.6	(0.57)	602.5	(0.65)	632.0	(0.77)
EU Total	302.1	337.6	(1.40)	370.9	(1.23)	429.2	(1.06)	557.8	(0.92)	610.1	(1.00)	639.7	(1.22)
Singapore	312.0	398.7	(2.82)	435.6	(2.59)	500.4	(2.41)	632.3	(1.61)	682.1	(2.41)	710.8	(3.35)
N. Ireland	253.2	363.4	(6.06)	388.1	(5.98)	438.2	(4.92)	547.9	(4.92)	591.9	(6.01)	616.6	(6.80)

5.7. Performance on Mathematics Proficiency Levels

The six proficiency levels used in the PISA 2015 mathematics assessment are the same as those established for the PISA 2012 assessments, when mathematics was the major area of assessment. There are six proficiency levels ranging from Level 1 to Level 6, as well as a 'Below Level 1' category (see Table 5.7 for a detailed description of each level). Students performing at Level 1 can answer the most basic PISA mathematics questions, when those questions are in familiar contexts, with all relevant information present, and when the questions call on routine procedures, which are always obvious. Level 6, in contrast, requires students to model complex mathematical problem situations, often presented in non-standard contexts, and to apply their understanding of symbolic and formal mathematical operations and relationships to the most difficult PISA mathematics items. Students performing below Level 1 can complete very direct and straightforward mathematical tasks, typically involving whole numbers and well-defined instructions.

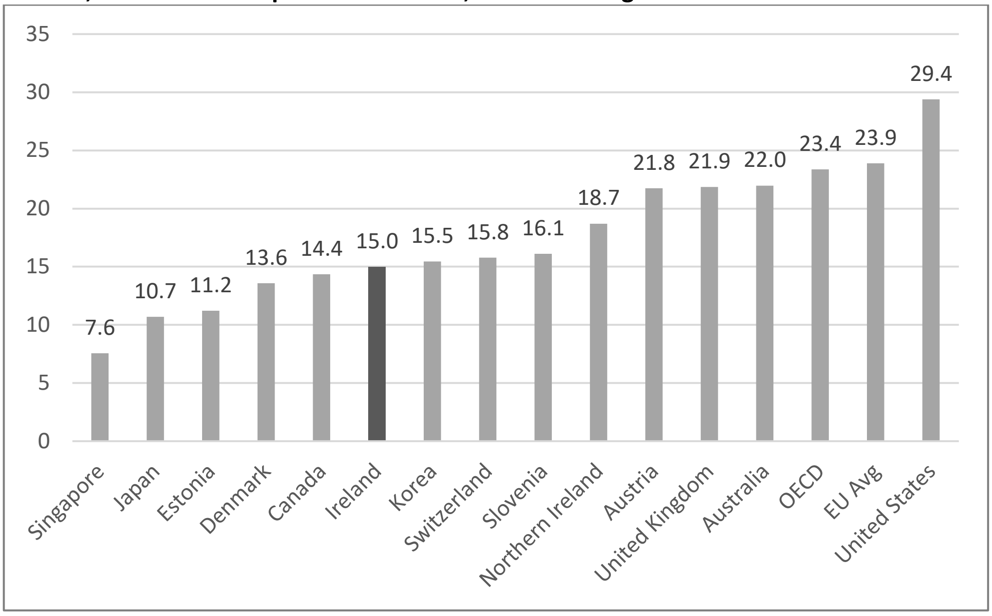
Table 5.7. Summary description of the six levels of proficiency on the mathematics scale and percentages of students achieving each level, in Ireland and on average across OECD and EU countries

Level (Cut-point)	Students at this level are capable of:	Ireland		OECD Avg		EU Avg	
		%	SE	%	SE	%	SE
6 (669 and above)	Conceptualising, generalising and using information based on their investigations and modelling of complex problem situations; using knowledge in relatively non-standard contexts; linking different information sources and representations and moving flexibly among them; applying their insight and understanding, along with mastery of symbolic and formal mathematical operations and relationships, to develop new approaches and strategies for addressing novel situations; reflecting on their actions and formulating and precisely communicating their actions and reflections regarding their findings, interpretations and arguments, and explaining why they were applied to the original situation. Students at this level are able to successfully complete the most difficult PISA items.	1.5	(0.2)	2.3	(0.1)	1.9	(0.1)
5 (607 to less than 669)	Developing and working with models of complex situations, including identifying constraints and specifying assumptions; selecting, comparing and evaluating appropriate problem-solving strategies for dealing with complex problems related to these models; working strategically using broad, well-developed thinking and reasoning skills, appropriate linked representations, symbolic and formal characterisations and insights pertaining to these situations; beginning to reflect on their work and formulating and communicating their interpretations and reasoning.	8.3	(0.5)	8.4	(0.1)	7.8	(0.1)
4 (545 to less than 607)	Working effectively with explicit models of complex, concrete situations that may involve constraints or making assumptions; selecting and integrating different representations (including symbolic representations) and linking them directly to aspects of real-world situations; using their limited range of skills and reasoning with some insight in straightforward contexts; constructing and communicating explanations and arguments based on their interpretations, arguments and actions.	21.2	(0.7)	18.6	(0.1)	18.2	(0.2)
3 (482 to less than 545)	Executing clearly described procedures, including those that require sequential decisions, making sufficiently sound interpretations to be a base for building a simple model or for selecting and applying simple problem-solving strategies; interpreting and using representations based on different information sources and reasoning directly from them; showing some ability to handle percentages, fractions and decimal numbers, and to work with proportional relationships; engaging in basic interpretation and reasoning	30.0	(0.9)	24.8	(0.2)	25.0	(0.2)
2 (420 to less than 482)	Interpreting and recognising situations in contexts that require no more than direct inference; extracting relevant information from a single source and making use of a single representational mode; employing basic algorithms, formulae, procedures or conventions to solve problems involving whole numbers; making literal interpretations of the results.	24.1	(0.9)	22.5	(0.2)	23.1	(0.2)
1 (358 to less than 420)	Answering questions involving familiar contexts where all relevant information is present and the questions are clearly defined; able to identify information and to carry out routine procedures according to direct instructions in explicit situations; can perform actions that are almost always obvious and follow immediately from the given stimuli.	11.5	(0.7)	14.9	(0.1)	15.1	(0.1)
Below Level 1 (less than 358)	Performing very direct and straightforward mathematical tasks, such as reading a single value from a well-labelled chart or table where the labels on the chart match the words in the stimulus and question, so that the selection criteria are clear and the relationship between the chart and the aspects of the contexts depicted are evident; performing arithmetic calculations with whole numbers by following clear and well-defined instructions.	3.5	(0.5)	8.5	(0.1)	8.8	(0.1)

OECD (2016b), Figure I.5.7.

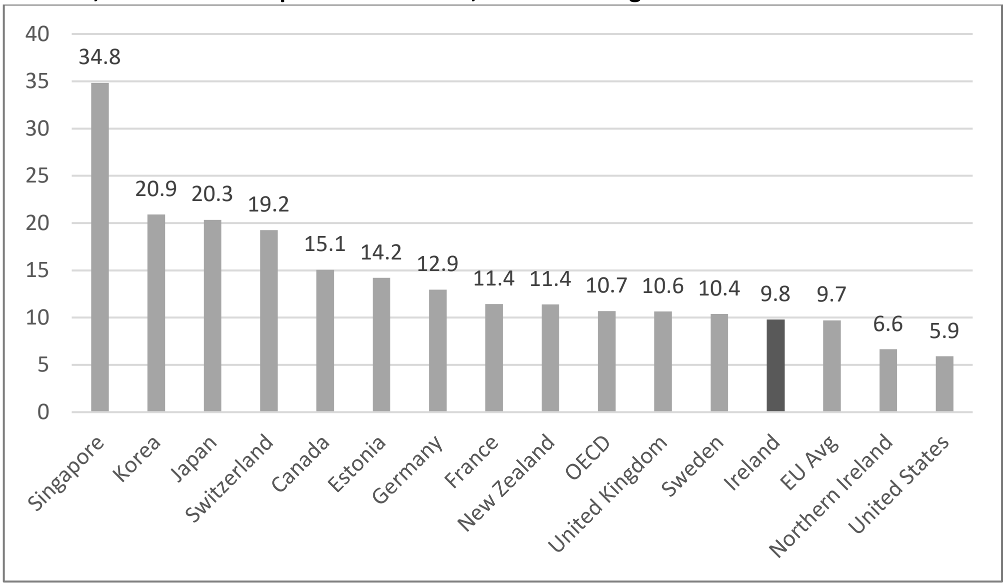
In Ireland, 15.0% of students perform below Level 2 on PISA mathematics (indicating weak performance), compared with 23.4% on average across OECD countries (Figure 5.4). Indeed, only a small number of comparison countries (Singapore with 7.6%, Japan with 10.7% and Estonia with 11.2%) have fewer students than Ireland performing below Level 2. On the other hand, 9.8% of students in Ireland perform at Levels 5-6 (indicating strong performance in mathematics), compared with an OECD average of 10.7% (Figure 5.5). In Singapore (the country with the highest average performance on PISA), 34.8% perform at Levels 5-6. Other countries with higher proportions of

Figure 5.4. Percentages of students performing below Proficiency Level 2 on the mathematics scale in Ireland, in selected comparison countries, and on average across OECD and EU countries



See E-Appendix Table A5.3 for percentages of students (and standard errors) at each proficiency level in Ireland on the mathematics, in selected comparison countries and on average across OECD countries.

Figure 5.5. Percentages of students performing at or above Proficiency Level 5 on the mathematics scale in Ireland, in selected comparison countries, and on average across OECD and EU countries



See E-Appendix Table A5.3 for percentages of students (and standard errors) at each proficiency level in Ireland on the mathematics scale, in selected comparison countries and on average across OECD countries.

students than Ireland performing at Levels 5-6 include Korea (20.9%), Japan (20.3%), Switzerland (19.2%) and Canada (15.1%). All of these countries also have higher average performance on PISA mathematics than Ireland. The pattern of performance across proficiency levels in Ireland is consistent with performance at key percentile markings. In general, lower-performing students in Ireland do well relative to their counterparts in other PISA countries, while higher-performing students do less well.

5.8. Gender Differences on Mathematics

In Ireland, male students achieved a mean score of 511.6 on PISA 2015 mathematics, while females achieved a mean score of 495.4 (Table 5.8). The difference (16.1 points) is statistically significant and is larger than the corresponding OECD average difference (7.9), also in favour of male students. Other comparison countries with relatively large differences in favour of male students include Germany (16.6 points), Japan (13.8), Switzerland (12.0), and the United Kingdom (11.6). In Korea, Singapore and Sweden, female students have marginally, though not statistically significantly, higher scores than male students. In Northern Ireland, male students have a mean score that is higher than that of females, by 6.6 score points. However, this difference is not statistically significant.

Table 5.8. Gender differences on the mathematics scale in Ireland, in selected comparison countries/ economies and on average across OECD and EU countries

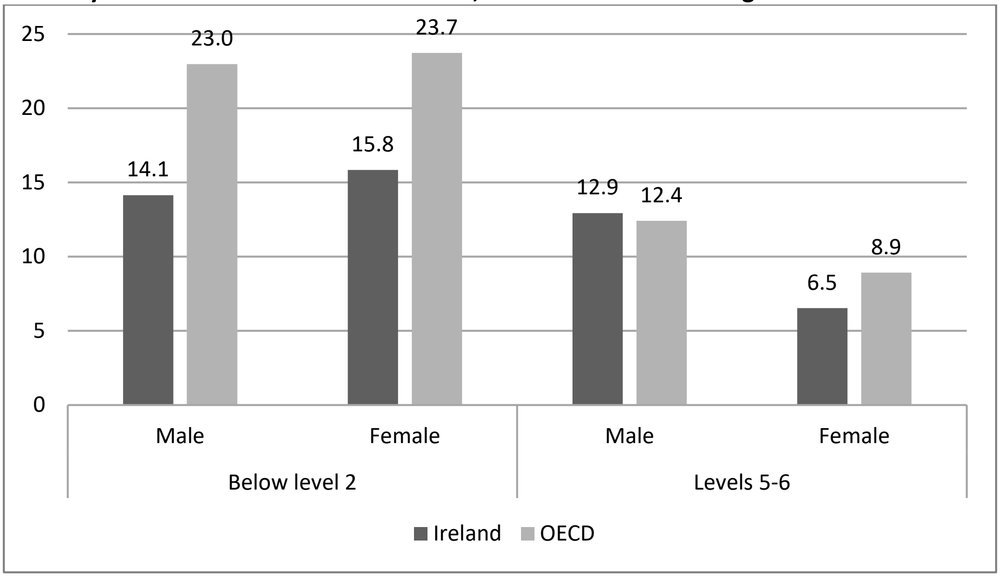
	Males		Females		Difference (males-females)	
	Mean	SE	Mean	SE	Score diff.	SED
Japan	539.3	(3.84)	525.5	(3.14)	**13.8**	(3.60)
Korea	520.8	(5.24)	527.8	(3.94)	-7.0	(5.63)
Switzerland	527.0	(3.23)	515.0	(3.51)	**12.0**	(3.32)
Estonia	522.1	(2.68)	516.9	(2.31)	5.2	(2.90)
Canada	520.2	(2.85)	511.1	(2.57)	**9.0**	(2.81)
Germany	514.1	(3.48)	497.5	(2.99)	**16.6**	(2.94)
Ireland	511.6	(2.96)	495.4	(2.42)	**16.1**	(3.42)

New Zealand	499.5	(3.44)	490.9	(2.72)	**8.5**	(4.23)
Sweden	492.8	(3.84)	495.1	(3.26)	-2.2	(3.27)
France	495.9	(2.92)	490.0	(2.62)	6.0	(3.64)
United Kingdom	498.2	(2.94)	486.6	(3.08)	**11.6**	(3.38)
United States	473.9	(3.63)	465.4	(3.44)	**8.5**	(3.14)
OECD Average	494.1	(0.56)	486.2	(0.51)	**7.9**	(0.61)
EU Average	490.5	(0.60)	483.6	(0.56)	**6.9**	(0.65)
Singapore	564.1	(2.10)	564.3	(1.75)	-0.1	(2.53)
Northern Ireland	496.0	(4.98)	489.4	(4.95)	6.6	(7.02)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

Gender differences can also be examined in terms of proficiency levels. In Ireland, the proportions of male and female students performing below Level 2 are broadly similar (14.1% and 15.8% respectively), and are lower than on average across OECD countries, where the respective proportions are also broadly similar (23.0% and 23.7% respectively) (Figure 5.6). In Ireland, 12.9% of male students, compared with 6.5% of females perform at Levels 5-6. On average across OECD countries, more males perform at Levels 5-6 (12.4%) compared with females (8.9%). Hence, equivalent proportions of male students in Ireland and on average across OECD countries perform at Levels 5-6, while fewer females in Ireland than on average across OECD countries perform at these levels.

Figure 5.6. Percentages of male and female students achieving below Proficiency Level 2 and at or above Proficiency Level 5 on the mathematics scale, in Ireland and on average across OECD countries



See E-Appendix Table A5.4 for percentages of male and female students at each proficiency level on the mathematics scale, in Ireland and on average across OECD countries.

5.9. Summary and Conclusion

This chapter described the performance of students in Ireland on two minor domains in PISA 2015 – reading literacy and mathematics – compared with their counterparts in selected countries, on average across OECD and EU countries, and in Northern Ireland. Both reading literacy and mathematics were assessed on computer in most participating countries in PISA 2015.

Students in Ireland achieved a mean score of 520.8 on reading literacy. This is significantly above the OECD average of 492.5 and ranks Ireland 3rd of 35 OECD countries, and 5th among all participating countries/economies. Only Singapore achieved a significantly higher mean score (535.1) than Ireland, while students in Ireland do no differ significantly in average performance from students in Hong Kong China, Canada, Finland, Estonia, Korea or Japan. The mean reading score in Northern Ireland (497.0) is significantly below the mean score in Ireland, and is not significantly different from the OECD average.

The range in reading achievement in Ireland (defined as the difference between the 5th and 95th percentiles) is 283.6 points, which is significantly smaller than on average across OECD countries (315.4).

Just 10.2% of students in Ireland perform at the lowest levels of reading proficiency (below Level 2) – about the same as in other high-performing countries including Estonia (10.6%), Canada (10.7%), Finland (11.1%) and Singapore (11.1%). On average across OECD countries, one-in-five students (20.1%) perform below Level 2. In Ireland, 10.7% of students perform at the highest proficiency levels in reading (Levels 5-6). This is about the same as in Germany (11.7%), Estonia (11.0%) and Sweden (10.0%), but fewer than in Singapore (18.4%), Canada (14.0%) and Finland (13.7%). On average across OECD countries, 8.3% perform at Levels 5-6 in reading.

In Ireland, female students significantly outperform male students on reading literacy, by 12.0 score points. This compares favourably with the average gender difference of 26.9 points across OECD countries. Countries with larger gender differences than Ireland include Finland (46.5), Korea (40.5), Sweden (39.2), and New Zealand (32.3). In Ireland, 8.0% of females and 12.3% of males perform below Proficiency Level 2, compared with 15.6% and 24.3% on average across OECD countries. Equal percentages of female and male students in Ireland perform at Levels 5-6, compared with OECD average percentages of 9.9% (females) and 6.8% (males).

In PISA 2015 mathematics, students in Ireland achieved a mean score of 503.7, and rankings of 13th of 35 OECD countries, and 18th of 70 participating countries/economies. Ireland's mean score is significantly above the OECD average score of 490.2. Fourteen countries/economics achieved significantly higher mean scores than Ireland including Singapore (which outperformed all other participating countries/economies), Hong-Kong China, Japan, Korea, Switzerland, Estonia and Canada. Countries performing at about the same level as Ireland include Belgium, Germany, Poland, Norway and Austria. Countries with significantly lower mean scores than Ireland include New Zealand, Australia, the United Kingdom, Israel and the United States.

The range in mathematics achievement in Ireland (the difference between the 5th and 95th percentiles) is 261.9 points, which is significantly smaller than the corresponding average across OECD countries (293.3), indicating a narrower range of performance in Ireland.

In Ireland, 15.0% of students perform at the lowest levels of mathematics proficiency (below Level 2), compared with an OECD average of 23.4%, indicating low performance. Comparison countries Singapore (7.6%), Japan (10.7%) and Estonia (11.2%) have fewer students than Ireland performing below Level 2. Just 9.8% of students in Ireland perform at the highest proficiency levels (Levels 5-6). The corresponding OECD average is marginally higher at 10.7%. A number of comparison countries have significantly higher percentages of students performing at Levels 5-6, including Singapore (34.8%), Korea (20.9%) and Japan (20.3%).

The mean mathematics score of male students in Ireland (511.6) is significantly higher than the mean score of female students (495.4). Among comparison countries, only Germany (16.6 points) has a difference in favour of male students that is similar to Ireland's (16.1). On average across OECD countries, male students significantly outperform female students by 7.9 score points. In Korea, female students have a mean score that is higher than that of males (by 7.0 score points), but the difference is not statistically significant. In Ireland, 14.1% of males and 15.8% of females perform below Proficiency Level 2 in mathematics, compared with 23.0% and 23.7% on average across OECD countries. Almost twice as many male students in Ireland perform at Proficiency Levels 5-6, compared with female students (12.4% and 6.5% respectively). On average across OECD countries, more male students (12.4%) than female students (8.9%) also perform at Levels 5-6.

Chapter 6: Student- and School-level Associations with Achievement in PISA 2015

In the previous two chapters, the performance of students in Ireland on PISA 2015 science, reading and mathematics was described in detail. In this chapter, a range of school and student background characteristics is considered, and the relationships between the various characteristics and students' performance in PISA 2015 are described. In doing so, the aim is to understand the contextual factors relating to the achievement of students in Ireland in PISA 2015. The focus of this chapter is on science, as it is the major domain in PISA 2015. However, throughout the chapter some reference is made to achievement in the reading and mathematics (the minor domains). Comparisons are also made with OECD countries on average and with other PISA countries and economies. Supplementary information in relation to all three domains is presented in the PISA 2015 E-Appendix available at www.erc.ie/pisa. Indices are scaled to have an OECD mean of 1 and standard deviation of 0, though there are small deviations from this on some indices.

This chapter is organised into two main sections. The first addresses student background characteristics and the second addresses school background characteristics.

6.1. Student Background Characteristics

This section examines students' social and home background, educational background, participation in education, and familiarity with and use of ICT, and considers how these factors relate to students' achievement.

6.1.1. Student social and home background and performance

Aspects of students' social and home backgrounds are related to their performance on the PISA domains. For instance, across OECD countries on average, students' socioeconomic profile explains a significant amount of the variation in their performance on PISA science, reading and mathematics (OECD, 2016b). Other student characteristics examined in this section include students' immigrant status and language background.

Student Economic, Social and Cultural Status

Students' economic, social and cultural status (ESCS) is a known predictor of student achievement and is associated with significant differences in student performance across many PISA countries and economies (OECD, 2016a). PISA assessments consistently find that ESCS is associated with performance at the student, school, and system levels. This section examines the relationship between student performance and ESCS at the student level.

In PISA 2015, the ESCS index is derived from three variables: home possessions (a composite of cultural, educational and material possessions, and books in the home), parental occupation, and parental education (Table 6.1). Cultural possessions include classic literature, books of poetry, books on art, music, or design, and musical instruments. Home educational resources include a desk and quiet place to study at home, as well as a computer for school work, and educational software. Material possessions (family wealth) include a student's own bedroom, MP3 player, and laptop or tablet computer, as well as the number of televisions, cars and bathrooms at the student's home. Books at home represents a student's estimation of the number of books (excluding magazines, newspapers and schoolbooks) that are in the home, using a scale ranging from 0-10 books, to more than 500 books.[31] Parental occupation and parental education are also derived from students' responses on the student questionnaire. Parental education is expressed in years calculated from parents' highest educational qualifications/attainments as reported by students. Parental occupation, as described by students, is scored on the International Socioeconomic Index (ISEI) following classification using the International Standard Classification of Occupation Index. Higher scores on the ESCS index indicate higher student economic, social and cultural status.

ESCS among students in Ireland (0.16) is significantly higher than among students across OECD countries on average (-0.04) (Table 6.1). Countries scoring similarly to Ireland on the ESCS index are Belgium (0.16), Israel (0.16), the Netherlands (0.16), and New Zealand (0.17). Among OECD countries, the highest ESCS scores are in Iceland (0.73), Denmark, (0.59) and Canada (0.53), and the lowest in Turkey (-1.43) and Mexico (-1.22) (OECD, 2016b, Table I.6.10). Students in Ireland have significantly higher levels of Parental Education than students across OECD countries on average, but do not differ from the OECD average on Parental Occupation (Table 6.1). Students in Ireland also have significantly higher levels of Home Possessions and Family Wealth than students on average across OECD countries, but have significantly lower levels of Home Educational Resources. Student average ESCS is presented by school SSP (DEIS) status, students' immigrant and language background, school type, and school fee status in the E-Appendix Tables A6.1 to A6.4.

Table 6.1. Mean scores on Economic, Social and Cultural Status (ESCS) and component scales, in Ireland and on average across OECD countries

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SE Diff
ESCS	0.16	(0.02)	0.84	-0.04	(0.00)	0.89	**0.20**	(0.02)
Parental occupation	52.8	(0.55)	21.4	51.8	(0.08)	21.1	1.00	(0.56)
Parental education	14.0	(0.05)	2.17	13.8	(0.01)	2.63	**0.20**	(0.05)
Home possessions	0.34	(0.02)	0.89	-0.01	(0.00)	0.86	**0.35**	(0.02)
Home possessions – component scales								
Home educational resources	-0.15	(0.02)	0.96	0.00	(0.00)	0.94	**-0.15**	(0.02)
Cultural possessions	0.01	(0.02)	1.01	0.02	(0.00)	0.97	-0.01	(0.02)
Family wealth	0.43	(0.02)	0.86	-0.01	(0.00)	0.85	**0.44**	(0.02)
Number of books in the home	159.9	(4.09)	199.02	158.3	(0.70)	199.8	1.60	(4.15)

Significant differences are in bold. Data were extracted from OECD (2016c, web-based tables).

Insight into how students' economic, social and cultural status is related to achievement can be gained from Table 6.2, which presents correlations between the ESCS index and its composite indices and performance on science among students in Ireland. A significant positive correlation in the moderate range (.36) is observed between ESCS and achievement in the science domain in Ireland. ESCS is also significantly positively correlated with achievement in reading (.35) and mathematics (.38) in Ireland (E-Appendix Table A6.5). The three indices from which ESCS is derived (Parental Occupation, Parental Education, and Home Possessions) all have significant positive correlations with achievement in science. The correlations are in the moderate range for Parental Occupation (.31) and Home Possessions (.27), and in the weak-to-moderate range for Parental Education (.24). Among the three ESCS composite indices, the highest correlation with science is

[31] The categories were recoded to provide national averages as follows: 0-10 books was recoded as 5 books, 11-25 books to 18 books, 26-100 books to 63 books, 101-200 books to 150.5 books, 201-500 books to 350 books, and more than 500 books to 750.5 books.

observed for Parental Occupation. Similarly, the highest correlations for both reading and mathematics are with Parental Occupation (E-Appendix Table A6.5). However, all three indices have significant positive correlations with achievement in the reading and mathematics domains.

Table 6.2. Correlations of ESCS and its component scales with science achievement, in Ireland

	Science		
	r	*t*	*p*
ESCS	**.356**	25.4	< .001
Parental occupation	**.311**	20.7	< .001
Parental education	**.236**	14.8	< .001
Home possessions	**.266**	19.0	< .001
Home possessions – component scales			
Home educational resources	**.183**	13.1	< .001
Cultural possessions	**.251**	19.3	< .001
Family wealth	**.063**	3.7	< .001
Number of books in the home	**.334**	21.5	< .001

Significant correlations are in bold. Df=80 (number of variance strata associated with balanced repeated replication (BRR) method of variance estimation).

Among the variables which comprise the Home Possessions index (home educational resources, cultural possessions, family wealth and average number of books in the home), the highest correlation with science is observed for books in the home (.33), followed by cultural possessions (.25) (Table 6.2). However, all variables have significant positive correlations with science. Similarly, all four variables have significant positive correlations with achievement in reading and in mathematics, and the strongest correlations for both are with books in the home (E-Appendix Table A6.5).

ESCS accounts for 12.7% of the variance in science performance in Ireland, and 12.9% across OECD countries on average (OECD, 2016b, Table I.6.3a). The score-point difference in science performance associated with one-unit (standard deviation) increase in overall ESCS is 37.6 in Ireland and 38.4 across OECD countries on average (OECD, 2016b, Table I.6.12a).

The OECD considers students as *socioeconomically disadvantaged* if they are among the 25% of students with the lowest values on the ESCS index in their country or economy, while students are considered *socioeconomically advantaged* if their ESCS values are among the top 25% in their country or economy (OECD, 2016b). The difference in science performance between students in the bottom quarter on the ESCS index and those in the top quarter is 79.8 score points in Ireland, and 88.0 score points on average across OECD countries (OECD, 2016b, Table I.6.3a). In Ireland, 26.4% of students in the bottom quarter of ESCS perform below Proficiency Level 2 in science, compared to 6.3% of students in the top quarter (OECD, 2016b, Table I.6.6a). Also, just 2.4% of students in the bottom quarter ESCS in Ireland perform at or above Level 5 in science, compared to 15.0% of the top quarter. Across OECD countries on average, 34.0% of students in the bottom quarter of ESCS are low performers in science (below Level 2) and 2.5% are top performers (Level 5 or above). In comparison, 9.3% of students in the top quarter of ESCS are low performers and 15.8% perform at the top levels.

Students' Immigrant and Language Background

PISA categorises a student as having an 'immigrant' background if the student was born in the test country and both parents were born elsewhere, or if the student and parents were born outside the test country (OECD, 2016b). Students are considered 'native' if they, and at least one parent, were born in the test country. Using this classification, a similar proportion of students in Ireland

(14.4%) as across OECD countries on average (12.5%) is categorised as having an immigrant background in PISA 2015 (OECD, 2016b, Table I.7.1). In PISA 2012, in comparison, 10.1% of students in Ireland, and 10.5% of students across OECD countries on average, were classified as 'immigrant' (Perkins, Shiel, Merriman, Cosgrove, & Moran, 2012).

In this report, the PISA 2015 indicator of students' immigrant background status is combined with an indicator of the language spoken in their home in order to describe achievement. As such, 85.6% of students in Ireland are classified as 'native', 7.3% as 'immigrant with English or Irish' spoken at home, and 7.1% as 'immigrant with other language' spoken at home. No significant differences are observed on overall science among students in Ireland based on immigrant and language background (Table 6.3), though this may arise from the large standard errors around the mean scores for the two immigrant groups. Native students have a mean score on science than is some 12.2 points higher than immigrant students who speak a language other than English or Irish at home. The only significant difference in achievement observed between the groups is on reading literacy, with native students scoring some 25 points higher than immigrant students who speak a language other than English or Irish (E-Appendix Table A6.6). No significant differences are observed between native and immigrant students in Ireland in achievement on mathematics (E-Appendix Table A6.6). Native students have similar scores to immigrant students who speak English or Irish at home on science, reading and mathematics, but have significantly lower social, economic and cultural status than these students (E-Appendix Table A6.2).

Table 6.3. Mean science scores by students' immigrant and language background, in Ireland

	Science			
	%	Mean	SE	SD
Native (ref)	85.6	505.1	(2.50)	88.03
Immigrant with Eng/Irish	7.3	507.9	(5.34)	92.88
Immigrant with other language	7.1	492.9	(5.22)	88.61

Significantly different mean scores are in bold (in comparison to the reference group).

6.1.2. Students' educational background

This section describes key aspects of students' educational background and their relationship to achievement. Although students in PISA 2015 in Ireland are aged 15 years, they vary by grade level from Second year through Fifth year. Students also differ in their early education experiences, in particular, whether or not they attended pre-primary education.

Grade Level

In Ireland, Third year students account for 60.5% of students in PISA 2015, Transition year students for 26.7%, Fifth year students for 10.9%, and Second year students for 1.9% (Table 6.4). Students in Third year score significantly higher on average than students in Second year and students in Fifth year on overall science (by 73 points and 14.8 points respectively), and significantly lower than students in Transition year (by 19 points). However, students in Third year do not differ significantly from students in Fifth year on reading and mathematics (E-Appendix Table A6.7). Students in Transition year score significantly higher than students in all other grades (including Fifth year) on science, reading and mathematics. Students in Second year score significantly lower than students in other grades on all three domains. Second years have a mean score on overall science that is at PISA Proficiency Level 2. The mean scores of all other grades are at Proficiency Level 3.

Table 6.4. Mean science scores by student grade (year) level in Ireland

	Science			
	%	Mean	SE	SD
Second Year	1.9	**427.8**	(9.83)	83.09
Third Year (Ref)	60.5	500.7	(2.48)	88.19
Transition Year	26.7	**520.0**	(3.80)	86.60
Fifth Year	10.9	**485.9**	(5.13)	87.73

Significantly different mean scores are in bold (in comparison to the reference group).

Students also differ by grade in their average ESCS. On average, Second year (-0.29) and Fifth year (-0.02) students have significantly lower scores on ESCS than both Third year (0.16) and Transition year students (0.28), while Transition year students have significantly higher ESCS than all other groups (E-Appendix Table A6.8).

Uptake of Junior Certificate Science

Data on students sitting Junior Certificate science in 2014 and 2015 were obtained from the State Examinations Commission and matched to PISA 2015 data for Ireland. This enabled the comparison of mean scores on PISA science for students who took Junior Certificate science with those who did not. Students who sat Junior Certificate science in 2014 and 2015 correspond to students in Third year, Transition year and Fifth year in PISA 2015. In total, data were matched for 97% of the PISA sample, and from this it was identified that 74.7% of the PISA sample took Higher level science, 15.3% took Ordinary level science, and 5.1% did not take Junior Certificate science (Table 6.5). Therefore, of the available sample (the 97% matched), 78.5% took science, 16.1% took Ordinary level science and 5.3% did not take Junior Certificate science. Using this breakdown to examine mean scores on PISA science shows that students who took Higher level science at Junior Certificate have significantly higher scores on PISA science than students who did not take Junior Certificate science. The difference between the groups is 98.9 score points. Students who took Ordinary level science at Junior Certificate do not differ significantly on PISA science from students who did not take Junior Certificate science.

Table 6.5. Mean science scores, by uptake of Junior Certificate science

	% Total	% Available	Mean	SE
Higher Level Science	74.7	78.5	**526.6**	(2.07)
Ordinary Level Science	15.3	16.1	417.9	(3.71)
Did not study science (ref)	5.1	5.3	427.7	(7.28)
Missing (not matched)	3.0		**512.6**	(8.02)
Second Year Students	1.9		427.8	(9.83)

Significantly different mean scores are in bold (in comparison to reference group).

The matching exercise identified that 5.3% of the students in the PISA sample did not study Junior Certificate science. However, population statistics available on the State Examinations Commission website (www.examinations.ie) indicate that 8.8% of Junior Certificate population in 2015 did not take science, a greater percentage than identified through the matching exercise. A possible explanation for the discrepancy is that schools not providing Junior Certificate science are clustered in the population of schools, with the result that those providing science are disproportionately represented in the PISA sample.

Pre-primary Education Attendance

According to parents, 83.8% of students in Ireland attended some form of pre-primary education (e.g., playschool, Montessori, pre-school, naíonra (Irish language pre-school), Early Start, Traveller pre-school programme) (Table 6.5)[32]. The comparable figure for OECD countries on average is 56.0%. Students who attended pre-primary education have a significantly higher mean score on science (513.0) than students who did not attend (483.1) (Table 6.6). Similarly, students who attended pre-primary education have higher mean scores on reading and mathematics, than students who did not attend (E-Appendix Table A6.9). The greatest difference between the groups is on reading literacy (32.7 points). Students also differ on average ESCS according to whether or not they attended pre-primary education, with those who attended pre-primary education having higher ESCS (0.24) than those who did not attend pre-primary education (-0.16).

Table 6.6. Mean science scores by pre-primary education attendance (parents' reports), in Ireland

	Science			
	%	Mean	SE	SD
Attended	83.8	**513.0**	(2.51)	87.02
Did not attend (ref)	16.2	483.1	(4.66)	88.63

Significantly different mean scores are in bold (in comparison to the reference group).

Differences in achievement also exist among students who attended pre-primary education in Ireland based on the duration of their attendance, as reported by students (Table 6.7). Students who reported attending pre-primary education for less than one year have lower scores on science, reading and mathematics than students who reported attending pre-primary education for one year or more, as well as those who reported that they did not attend (Table 6.7 and E-Appendix Table A6.10). However, just 2.5% of students reported attending pre-primary education for less than one year. It should also be noted that 10.8% of students could not remember if they had attended pre-primary education, and 6.3% reported not attending, in contrast to the 16.2% reported by parents.

Table 6.7. Mean science scores by duration of pre-primary attendance (students' reports), in Ireland

	Science			
	%	Mean	SE	SD
Less than one year (ref)	2.5	450.7	(8.25)	90.25
Between one and two years	36.6	**509.2**	(2.81)	86.14
Between two and three years	31.6	**507.0**	(2.89)	87.13
Three years or more	12.3	**496.3**	(5.19)	92.82
I did not attend	6.3	**488.8**	(4.73)	82.30
I don't remember	10.8	**503.7**	(4.24)	93.80

Significantly different mean scores are in bold (in comparison to the reference group).

6.1.3. Students' participation in education

In this section, student participation in education and its relationship to achievement are described. Of particular interest are students who are at risk of leaving school early, as well as those who skip days at school, and those who frequently arrive at school late. Data were gathered from students via the student questionnaire.

[32] Students in Ireland in PISA 2015 (aged 15 years) would not have availed of one or more free pre-school years, as the Early Childhood Care and Education (ECCE) Scheme was not introduced until 2010.

Early School Leaving Risk

Students in Ireland deemed at risk of leaving school early are those who indicated the Junior Certificate as the highest level of formal education they expect to complete. On this basis, the majority of students (87.5%) are considered not at risk of early school leaving. Compared to those students, the 12.5% of students at risk of early school leaving have a significantly lower mean score on overall science (Table 6.8), reading and mathematics (E-Appendix Table A6.11). The score point difference between the groups is similar for science (49.2) and reading (48.5) and slightly lower for mathematics (44.5). The students deemed at risk also have a significantly lower average ESCS (-0.07) than those deemed not at risk (0.20).

Table 6.8. Mean scores for science by early school-leaving risk, in Ireland

	Science			
	%	Mean	SE	SD
Not at risk (Ref)	87.5	509.3	(2.42)	87.57
At risk	12.5	**460.1**	(4.06)	84.57

Significantly different mean scores are in bold (in comparison to the reference group).

Absence from School and Lateness

PISA asked students about the frequency with which they 'skipped a whole school day' and 'arrived late for school' in the two weeks before PISA testing. In Ireland, three quarters of students (75.6%) had not skipped any days in the previous two weeks, while one fifth (20.5%) had skipped one or two days, and 3.9% had skipped three days or more (Table 6.9). The numbers skipping school in Ireland have increased considerably from PISA 2012, which reported just 3.3% of students skipping one or two days, and 0.7% skipping three or more days (Perkins et al., 2013).[33] There is little difference in the percentages of students skipping days across school sector and gender types in 2015 (E-Appendix Table A6.12). A slightly lower percentage of students in schools in the SSP (72.1%) compared to students in non-SSP schools (76.3%) had not skipped any days in the previous two weeks (E-Appendix Table A6.13). On average across OECD countries, 80.3% of students had not skipped any days in the two weeks prior to PISA testing (OECD, 2016c, Table II.3.1).

In PISA 2015, students in Ireland who skipped days at school during the two weeks prior to testing have significantly lower scores on science compared to students who did not skip days, with score differences of -18.6 points for those who skipped one or two days and -36.4 points for those who skipped three or more days (Table 6.9). Similarly, students who skipped days score significantly lower on reading and mathematics than students who did not skip any days (E-Appendix Table A6.14). The greatest difference in achievement across domains is observed for mathematics, with a difference of 40.6 points between students who did not skip any days and students who skipped three or more days.

Table 6.9. Mean science scores by frequency of skipping school in the two weeks prior to testing, in Ireland

	Science			
	%	Mean	SE	SD
None (Ref)	75.6	508.2	(2.37)	88.4
1 or 2 days	20.5	**489.6**	(3.87)	86.42
3 or more days	3.9	**471.8**	(7.25)	93.84

Significantly different mean scores are in bold (in comparison to the reference group).

[33] Note that PISA 2012 distinguished between skipping school 'without permission' and absence from school 'due to illness or an appointment'. In Ireland, PISA 2015 did not make a similar distinction.

In Ireland, 31.1% of students reported arriving late for school on at least one occasion in the two weeks prior to PISA testing, compared to 44.4% across OECD countries on average (OECD, 2016c, Table II.3.1). In Ireland, students who reported arriving late for school on at least one occasion in the two weeks before testing have significantly lower scores on science (Table 6.10), reading and mathematics (E-Appendix Table A6.15) in PISA 2015. The greatest differences across domains are observed for reading, with a 20 point difference between students not late on any occasion and students late one or two times, and a 33.5 point difference between students not late on any occasion and students late three or more times. Students in vocational schools reported arriving late more often than students in other school types (E-Appendix Table A6.16). Also, a slightly greater percentage of students in SSP schools (39.8%) reported arriving late at least once in the previous two weeks, compared to students in other schools (29.5%) (E-Appendix Table A6.17).

Table 6.10. Mean science scores by frequency of arriving late for school in the two weeks prior to testing, in Ireland

	Science			
	%	Mean	SE	SD
None (Ref)	68.9	509.7	(2.29)	87.10
1 or 2 times	24.0	**491.8**	(3.88)	89.15
3 or more times	7.1	**478.6**	(5.64)	91.96

Significantly different mean scores are in bold (in comparison to the reference group).

6.1.4. Students' familiarity with, and use of, information and communications technology (ICT)

PISA 2015 included a computer familiarity questionnaire, which was administered to students in Ireland and 29 other OECD countries. The questionnaire addressed students' experience with, and use of, computers at and outside of school, as well as their attitudes towards computers. Clusters of items were used to construct specific indices assessing students' interest in ICT, perceived competence and autonomy in using ICT, practices of ICT use, and use of ICT as a topic of social interaction.[34] The indices are scaled to have an OECD mean of 0 and standard deviation of 1, with higher scores indicating greater levels of the corresponding construct.

Students in Ireland have significantly greater levels of interest in ICT than students on average across OECD countries (a mean score of 0.32 for Ireland versus an OECD average of 0.00) (Table 6.11). Interest in ICT was assessed by asking students to what extent they agree with items such as 'I am really excited discovering new digital devices or applications', and 'the Internet is a great resource for obtaining information I am interested in' (e.g., news, sports, dictionary). Students in Ireland also have significantly greater perceived competence (mean score of 0.21) and autonomy (mean score of 0.11) in using ICT than students on average across OECD countries (OECD means of 0.01 for competence and 0.01 for autonomy). Students' perceived competence in using ICT was assessed by asking to what extent they agree with items such as 'I feel comfortable using digital devices that I am less familiar with', and 'when I come across problems with digital devices, I think I can solve them'. Students' perceived autonomy with regard to ICT was assessed by asking students the extent to which they agreed with index items such as 'if I need new software, I install it by myself', and 'if I have a problem with digital devices I start to solve it on my own'.

[34] Selected indices and their relationship to achievement are described in this report. Further analyses will be published in a later report on ICT based on PISA 2015 data.

Table 6.11. Mean scores on ICT familiarity and use indices, in Ireland, and across OECD countries on average

	Ireland		OECD		Difference	
	Mean	SE	Mean	SE	IRL-OECD	SED
Students' ICT interest	0.32	(0.02)	0.00	(0.00)	**0.32**	(0.02)
Students' perceived ICT competence	0.21	(0.01)	0.01	(0.00)	**0.20**	(0.01)
Students' perceived autonomy with regard to ICT	0.11	(0.02)	0.01	(0.00)	**0.10**	(0.02)
Use of ICT at school in general	-0.38	(0.03)	0.01	(0.00)	**-0.39**	(0.03)
ICT use outside of school for schoolwork	-0.42	(0.02)	0.00	(0.00)	**-0.42**	(0.02)
ICT use outside of school, leisure	0.00	(0.01)	-0.01	(0.00)	0.01	(0.01)
ICT use as a topic in social interaction	-0.07	(0.01)	0.01	(0.00)	**-0.08**	(0.01)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

Items assessing the use of ICT 'at school in general' and 'outside of school for schoolwork' asked students about the frequency with which they perform certain ICT tasks such as 'using email' (at school in general), 'browsing the Internet for schoolwork' (at school in general), 'browsing the Internet for schoolwork (e.g., for preparing an essay or presentation)' (outside of school) and 'doing homework on a computer' (outside of school). On the ICT Use at School in General and ICT Use Outside of School indices, the mean scores of students in Ireland (-0.38 and -0.42 respectively) are significantly below the corresponding OECD averages (Table 6.11). Therefore, students in Ireland use ICT at school in general and outside of school for schoolwork considerably less often than students across OECD countries on average. Germany scores similarly to Ireland on the Use of ICT at School in General (-0.42) and Use of ICT Outside of School for Homework (-0.38) indices. OECD countries scoring lower than Ireland on these indices include Japan (-1.05 for Use at School and -1.21 for Use Outside of School for Schoolwork), Korea (-0.95 for Use at School), and Finland (-0.52 for Use Outside of School for Schoolwork). Denmark is the highest scoring OECD country on both indices (0.74 for Use at School and 0.33 for Use at Home for Schoolwork).

PISA asked students to indicate the frequency with which they use digital devices outside of school for a range of leisure activities such as 'playing one-player games', 'browsing the Internet for fun videos' (e.g., YouTube), and 'downloading music, films, games or software from the Internet'. Students in Ireland do not differ significantly from students across OECD countries on average on the use of ICT Outside of School for Leisure index (Table 6.11). PISA also asked students to what extent they agree with statements about their use of ICT as a topic in social interactions, for example, 'to learn something new about digital devices, I like to talk about them with my friends', and 'I like to meet friends and play computer and video games with them'. Students in Ireland score slightly, but significantly, lower than students across OECD countries on average on the Use of ICT as a Topic in Social Interaction index (-0.07 for Ireland versus OECD average of 0.01) (Table 6.11).

In Ireland, clear gender differences are observed on the majority of the ICT familiarity and use indices (Table 6.12). Male students score significantly higher than female students on Perceived Competence with regard to ICT use (0.31 for males versus 0.11 for females) and Perceived Autonomy with regard to ICT use (0.30 for males versus -0.09 for females), as well as on Use of ICT Outside of School for Leisure (0.13 for males and -0.14 for females) and the Use of ICT as a Topic in Social Interaction (0.16 for males versus -0.31 for females) indices. Female students score significantly higher than male students on Use of ICT Outside of School for Homework (-0.35 for females versus -0.48 for males); however, both female and male students score well below the respective OECD averages on this index (-0.03 for females and 0.03 for males). Similarly, both male students and female students score well below the respective OECD averages on the Use of ICT at School in General index (-0.38 for males and -0.38 for females in Ireland versus OECD averages of 0.07 for males and -0.04 for females). Male and female students do not differ in their overall interest in ICT and both groups of students score well above the OECD average scores on the ICT Interest index (0.30 for males and 0.34 for females in Ireland versus OECD averages of 0.03 for males and -0.03 for females).

Table 6.12. Mean scores on ICT familiarity and use indices, by gender, in Ireland

	Males		Females		Difference	
	Mean	SE	Mean	SE	M-F	SED
Students' ICT interest	0.30	(0.02)	0.34	(0.02)	-0.04	(0.03)
Students' perceived ICT competence	0.31	(0.02)	0.11	(0.02)	**0.20**	(0.03)
Students' perceived autonomy with regard to ICT	0.30	(0.02)	-0.09	(0.02)	**0.39**	(0.03)
Use of ICT at school in general	-0.38	(0.03)	-0.38	(0.03)	0.00	(0.04)
ICT use outside of school for schoolwork	-0.48	(0.03)	-0.35	(0.02)	**-0.13**	(0.04)
ICT use outside of school, leisure	0.13	(0.02)	-0.14	(0.01)	**0.27**	(0.02)
ICT use as a topic in social interaction	0.16	(0.02)	-0.31	(0.02)	**0.47**	(0.03)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

Students' interest in ICT has no significant association with achievement in science (Table 6.13) or mathematics (E-Appendix Table A6.18), but has a weak significant association with achievement in reading (E-Appendix Table A6.18). Students' perceived ICT competence and autonomy both have significant positive associations with achievement in science (Table 6.13), as well as in reading literacy and mathematics (E-Appendix Table A6.18). The associations are in the weak-to-moderate range for science, and weak (ICT Competence) and weak-to-moderate range (ICT Autonomy) for both reading and mathematics. Across science, reading literacy and mathematics, the remaining ICT familiarity and use variables (Use of ICT at School in General, Use of ICT Outside of School for Schoolwork, Use of ICT Outside of School for leisure, and use of ICT as a Topic of Social Interaction) have significant weak negative associations with achievement. The correlations of the ICT familiarity and use indices with achievement should be interpreted in light of Ireland's low scores on the indices, which, in particular, indicate below average engagement with ICT at school in general and outside of school for schoolwork. It is also possible that lower-achieving students in Ireland are more engaged with ICT both at school in general and outside of school.

Table 6.13. Correlations of ICT familiarity and use indices with achievement in science, in Ireland

	Science		
	r	*t*	*p*
Students' ICT interest	.029	1.61	NS
Students' perceived ICT competence	**.124**	7.75	< .001
Students' perceived autonomy with regard to ICT	**.176**	10.35	< .001
Use of ICT at school in general	**-.108**	-6.00	< .001
ICT use outside of school for schoolwork	**-.054**	-3.38	< .001
ICT use outside of school, leisure	**-.070**	-4.12	< .001
ICT use as a topic in social interaction	**-.036**	-2.00	< .05

Significant correlations are in bold. Df=80 (number of variance strata associated with balanced repeated replication (BRR) method of variance estimation).

Table 6.14 presents mean scores on science for students in Ireland who had taken a computer-based test at least once prior to PISA 2015 and those that had never taken a computer-based test before. Almost three-in-five (57.2%) students in Ireland, and more female students (60.5%) than male students (54.0%), had never taken a computer-based test before PISA 2015 (Table 6.14 and E-Appendix Tables A6.19 to A6.21). Students who had never taken a computer-based test before have a significantly lower mean score on science than students who had taken a computer-based test at least once before PISA 2015 (a difference of 10.2 points). Similar significant differences are found between the groups on both reading (9.6 points) and mathematics (8.8 points) (E-Appendix Table A6.22). This suggests that students without prior experience of computer-based testing may be at a disadvantage when taking the PISA tests. However, these students also have significantly lower average ESCS than students who had taken a computer-based test at least once before (E-Appendix Table A6.23).

Table 6.14. Mean science scores for students who had taken a computer-based test at least once prior to PISA 2015 and students who had never taken a computer-based test, in Ireland

	Science			
	%	Mean	SE	SD
Yes, at least once	42.8	**510.0**	3.09	89.1
No, never (ref)	57.2	499.8	2.64	87.6

Significantly different mean scores are in bold (in comparison to the reference group) ($p < .05$).

6.2. School Background Characteristics

Schools differ in important characteristics such as average ESCS, the organisation of the school, the overall climate of the school, and the degree to which parents are involved in the activities of the school. Characteristics such as these are likely to influence the performance of students. In this section, the findings relating to these school background characteristics and their relationships to achievement are presented. As schools also differ in other important ways such as their location, gender composition, funding, and SPP (DEIS) status, these factors are also considered. Data were gathered via the student, parent, and school principal questionnaires. Student-level data are mostly used throughout this section. However, where school-level data are used (e.g., school average ESCS), all students in a school are assigned the value appropriate to their school.[35]

6.2.1. Between- and within-school variance in science performance

Across OECD countries on average, 30.1% of the total variation in science performance lies between schools and the remainder lies within schools (OECD, 2016b, Table I.6.9). Total variation in science performance in Ireland amounts to 88.1% of the OECD average variation, with 11.5% between schools and 76.2% within schools.[36] In some countries, such as the Netherlands, Bulgaria, and Hungary, over 50% of the differences in science performance (as a percentage of the OECD average variation) lie between schools. In others, (e.g., Finland, Iceland, and Norway), between school differences account for less than 10% of the variation in performance.

[35] Results of tests that use school aggregates must be interpreted with caution, as the approach can result in over-estimates of significance when applying statistical tests (Perkins et al., 2012).
[36] As the PISA 2015 sampling approach in Ireland was age-based, and not grade-based, the within school variation includes some grade-based performance differences (OECD, 2016b).

6.2.2. School-related variation in ESCS and performance

This section examines the relationship between student performance and ESCS at the school level. In Ireland, the overall school average ESCS is 0.16 (SE = 0.02, SD = 0.38) (E-Appendix Table A6.24), with an average of -0.28 for schools in the SSP under DEIS, and an average of 0.24 for schools not in the SSP (E-Appendix Table A6.25). On average across OECD countries, school average ESCS is -0.04 (E-Appendix Table A6.24). A significant positive correlation in the moderate range is observed between school average ESCS and achievement in science (.29) among students in Ireland (E-Appendix Table A6.26). A one unit increase in school ESCS is associated with a 39.0 point increase in science at the school level in Ireland, and a 69.0 point increase at the school level across OECD countries on average (OECD, 2016b, Table I.6.12a). Significant positive correlations are also observed between school average ESCS and achievement in reading (.30) and mathematics (.31) in Ireland (E-Appendix Table A6.26).

PISA classifies schools by level of disadvantage based on the distribution of the school-level ESCS within each country/economy. Schools in the bottom quarter of school ESCS within a country/economy are designated as socioeconomically disadvantaged and schools within the top quarter as advantaged (OECD, 2016b, Table I.6.11). Students in socioeconomically disadvantaged schools score well below the OECD average (493.2 points) in PISA science in Ireland (a mean score of 468.4, SE = 5.79) and across OECD countries on average (a mean of 442.2, SE = 0.87) (OECD, 2016b, Table I.6.11). Students in socioeconomically disadvantaged schools also score lower on PISA science than students in economically average schools and students in advantaged schools both in Ireland and across OECD countries on average. Indeed, a difference of 67.3 score points in science is observed between students in socioeconomically disadvantaged schools and students in advantaged schools in Ireland. Across the OECD countries on average, the difference in science performance between students in disadvantaged and advantaged schools is 103.8 points.

In Ireland, 17.7% of the variation in students' ESCS lies between schools, and 82.3% within schools. Similarly, across OECD countries on average, between school differences account for 23.5% of the variation in students' ESCS, and within school differences account for 76.5% (OECD, 2016b, Table 1.6.10). In Ireland, and across OECD countries on average, therefore, greater diversity in students' socioeconomic status exists among students in the same school, than among student's attending different schools. The correlation between student ESCS and school average ESCS in Ireland is in the moderate-to-strong range (.45). Together, student and school average ESCS explain 14.9% of the overall variance in science performance in Ireland, 61.5% of between school variance, and 7.6% of within school variance (OECD, 2016b, Table I.6.12a). This compares to 22.4% across OECD countries on average (62.6% between and 3.6% within).

6.2.3. School organisation and performance

Next, the performance of students in Ireland in PISA 2015 is described according to various characteristics of schools nationally. Specifically, students' performance is described in relation to the gender composition, fee-status, and location (rural, town, or city) of their school, and whether or not the school is in receipt of additional resources as part of the School Support Programme (SSP) under DEIS.

School SPP (DEIS) Status

Students attending schools in the SSP under DEIS have a significantly lower mean score on science compared to students in non-SSP schools (Table 6.15). The difference, 48.3 score points, is statistically significant. Similarly, students in SSP schools have significantly lower mean scores in reading and in mathematics than students in non-SPP schools, with differences of 49.8 points for reading and 44.8 points for mathematics (E-Appendix Table A6.27).

Table 6.15. Mean scores on science by school SSP (DEIS) status, in Ireland

		Science		
	%	Mean	SE	SD
Non-SSP (ref)	84.0	510.3	(2.35)	86.29
In SSP	16.0	**462.0**	(6.97)	91.31

Significantly different mean scores are in bold (in comparison to the reference group).

Sector and Gender Composition and Fee-Paying Status

In Ireland, schools are categorised into five types based on sector and gender composition: girls' secondary, boys' secondary, community/comprehensive, mixed secondary and vocational. Table 6.16 presents mean scores on PISA science by each school type. Students in boys' secondary schools have the highest mean scores on science (521.7), while students in vocational schools have the lowest (483.1). Indeed, students in vocational schools have a mean science score that is significantly lower than students in mixed secondary, girls' secondary, and boys' secondary schools. No significant difference in science scores is found between vocational schools and community/comprehensive schools. Comparisons of scores in reading and mathematics similarly show that students in vocational schools score significantly lower than students in boys', girls' and mixed secondary schools, but do not differ significantly from students in community/ comprehensive schools on either domain (E-Appendix Table A6.28). Students in vocational schools have significantly lower scores on the ESCS index than students in girls', boys', and mixed secondary schools, but do not differ in ESCS from students in community/comprehensive schools (E-Appendix Table A6.29).

Table 6.16. Mean scores on science by school sector and gender composition, in Ireland

		Science		
	%	Mean	SE	SD
Girls' secondary	21.1	**511.2**	(3.58)	80.11
Boys' secondary	16.7	**521.7**	(5.52)	91.24
Community/comprehensive	17.6	494.7	(3.89)	86.53
Mixed secondary	18.6	**510.3**	(6.49)	89.15
Vocational (ref)	26.0	483.1	(5.69)	91.19

Significantly different mean scores are in bold (in comparison to the reference group).

Students attending fee-paying schools have significantly higher scores on the ESCS index (0.86) than students at non-fee-paying schools (0.09) (E-Appendix Table A6.30). These students also significantly outperform students in non-fee-paying schools on all three PISA 2015 domains (E-Appendix Table A6.31). Students in fee-paying schools have a mean score on science (549.8) that is over half of one standard deviation higher than the mean score of students in non-fee-paying schools (497.9) (Table 6.17).

Table 6.17. Mean scores on science by school fee-paying status, in Ireland

		Science		
	%	Mean	SE	SD
Non-fee-paying (ref)	90.9	497.9	(2.58)	88.0
Fee-paying	9.1	**549.8**	(5.54)	83.5

Significantly different mean scores are in bold (in comparison to reference group).

School Location

Data on school location (rural, town, or city) were obtained from the PISA Schools Questionnaire, and are based on information provided by school principals. In Ireland, around half of students attend schools in towns (50.9%), while 29.2% attend schools in cities, and 19.9% attend schools in rural areas. Students in city schools have the highest mean score on science (514.9), but do not differ significantly on science from students in town or rural schools (Table 6.18). Comparisons of mean scores on reading literacy reveal no significant differences in achievement based on school location (E-Appendix Table A6.32). However, scores on mathematics are significantly higher in city schools compared to town schools (E-Appendix Table A6.32). Students in city schools also have higher average ESCS than students in town or rural schools (E-Appendix Table A6.33).

Table 6.18. Mean scores on science by school location, in Ireland

	Science			
	%	Mean	SE	SD
Town (ref)	50.9	499.9	(3.59)	88.61
City	29.2	514.9	(5.66)	90.48
Rural	19.9	495.2	(5.42)	86.29

Significantly different mean scores are in bold (in comparison to the reference group).

6.2.4. School and classroom climate and performance

PISA 2015 assessed various aspects of school climate that can impact on performance. Specifically, PISA asked principals about the extent to which aspects of student and teacher behaviours hinder learning. Student factors include truancy, skipping classes, and use of alcohol and illegal drugs by students (E-Appendix Table A6.34). Teacher factors include teacher absenteeism, staff resisting change, and teachers not being well prepared for class (E-Appendix Table A6.35). According to principals in Ireland, truancy is the student factor that hinders learning the most; over half of students (51.6%) are in schools whose principals report learning is hindered by truancy 'to some extent' or 'a lot'. Staff resistance to change was identified as the teacher factor that hinders learning the most; some 27.2% of students are in schools whose principals report this issue hinders learning 'to some extent' or 'a lot'. PISA also constructed two indices of school climate (Student Factors Affecting Climate and Teacher Factors Affecting Climate) using the student factor and teacher factor items, with higher scores indicating greater perceived hindrance to learning. Compared to OECD countries on average, Ireland does not differ significantly in terms of the extent to which principals report that student or teacher factors (i.e., student or teacher behaviours) affecting school climate hinder students' learning (Table 6.19).

Table 6.19. Mean scores on indices measuring school climate, in Ireland, and on average across OECD countries

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Student factors affecting climate	0.04	(0.08)	0.91	0.01	(0.01)	0.93	0.03	(1.30)
Teacher factors affecting climate	0.13	(0.07)	0.87	0.05	(0.01)	0.91	0.08	(0.07)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference. OECD data were extracted from OECD 2016c, Tables II.3.15 and II.3.20.

Student Factors Affecting School Climate has a weak negative, but significant, relationship to achievement in science (Table 6.20), reading and mathematics (E-Appendix Table A6.36). Teacher Factors Affecting School Climate has no significant relationship with achievement in science, reading, or mathematics. Teacher Factors is not associated with student ESCS, while Student Factors has a weak-to-moderate negative association (*r*=-.20) (E-Appendix Table A6.37).

Table 6.20. Correlations of indices measuring school climate with science achievement, in Ireland

	Science		
	r	*t*	*p*
Student factors affecting climate	**-.155**	-4.43	< .001
Teacher factors affecting climate	-0.16	-0.38	NS

Significant correlations are in bold. Df=80 (number of variance strata associated with balanced repeated replication (BRR) method of variance estimation).

Characteristics of Science Classes

In PISA 2015, students were asked about particular characteristics of their sciences classes that can impact on performance, including the disciplinary climate and the amount of support provided by teachers. This section describes these characteristics and their relationship to performance among students in Ireland.

Table 6.21 presents mean scores on a range of indices describing aspects of science classes for students in Ireland and on average across OECD countries.

Table 6.21. Mean scores on indices measuring characteristics of science classes, in Ireland

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Disciplinary climate in science classes	0.09	(0.02)	1.03	0.00	(0.00)	0.97	**0.09**	(1.03)
Teacher support in science class	0.08	(0.02)	0.98	-0.02	(0.00)	0.97	**0.10**	(0.02)
Inquiry-based science teaching and learning practices	0.01	(0.02)	0.80	0.01	(0.00)	0.96	0.00	(0.02)
Adaptation of instruction	-0.02	(0.02)	0.95	0.01	(0.00)	0.98	-0.03	(0.02)
Teacher directed science instruction	-0.02	(0.02)	0.93	0.01	(0.00)	0.97	-0.03	(0.02)
Perceived feedback	0.00	(0.02)	0.92	0.00	(0.00)	(0.97)	0.00	(0.02)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference. All indices have an OECD mean of 0 and standard deviation of 1, with some slight deviations. Data were extracted from OECD (2016c).

The first index refers to the disciplinary climate of science classes. A key role of teachers is to create and maintain a classroom environment that is conducive to learning, and to do so requires ensuring students can listen and concentrate on their work (OECD, 2016c). Hence, PISA asked students about the frequency with which various disciplinary incidents occur in their science classes (e.g., ‘students don’t listen to what the teacher says’ and ‘there is noise and disorder’) (E-Appendix Table A6.38). PISA then constructed an index of disciplinary climate (Disciplinary Climate in Science Classes), with high scores indicating a better climate. Compared to students across OECD countries on average, students in Ireland report a better disciplinary climate in science classes (Table 6.21). Those students perform better in science than other students, after school and student ESCS are taken into account. A one-unit increase on the Disciplinary Climate index is associated with a 6.5 point increase on overall science in Ireland, and an 10.9 point increase on science for OECD countries on average, after school and student ESCS are taken into account (OECD, 2016c, Table II.3.10). In Ireland, there is no difference in disciplinary climate in science classes between advantaged and disadvantaged schools (as defined by the OECD) based on students’ reports (OECD, 2016c, Table II.3.11). However, across OECD countries on average, students in advantaged schools report a better disciplinary climate in science classes compared to students in disadvantaged schools.

The second index refers to teacher support in science class. Students need support from teachers if they are to maximise the learning available to them in class (OECD, 2016c). Therefore, PISA asked students how often teachers perform a range of supportive actions in science class (e.g., ‘the teacher shows an interest in every students’ learning’ and ‘the teacher gives students an opportunity to express opinions’) (E-Appendix Table A6.39). Students’ responses were combined to construct the Teacher Support in Science Classes index, with positive values indicating that students perceive their teachers as supportive (OECD, 2016c). Students in Ireland are positive overall about the support provided by teachers in science classes; for example, over three quarters of students report that their teacher ‘shows an interest in every students’ learning’ (75.9%) and ‘helps students with their learning’ (77.3%) in ‘every’ or ‘most’ science classes (E-Appendix Table A6.39). Compared to students in OECD countries on average, students in Ireland report more frequent support from their teachers in science class (Table 6.21). In Ireland, and across OECD countries on average, students in disadvantaged schools (as defined by the OECD) report greater support from teachers compared to students in advantaged schools (OECD, 2016c, Table II.3.23). Accounting for differences in school and student socioeconomic profile, the change in science score per unit increase on the index of teacher support in science classes is 2.9 points in Ireland and 2.0 points across OECD countries on average.

The third index is Inquiry-based Science Teaching and Learning practices. This index is constructed from nine statements which measure the extent to which science teachers encourage students to enquire about science problems using scientific methods, including experiments (OECD, 2016c). Examples include ‘students are given opportunities to explain their ideas’, and ‘students spend time in the laboratory doing practical experiments’ (E-Appendix Table A6.40). Higher scores on the index represent more frequent occurrence of inquiry-based teaching practices, as perceived by students. Students in Ireland do not differ from students on average across OECD countries in terms of mean score on the inquiry-based teaching and learning index (Table 6.21). Across OECD countries on average, more inquiry-based instruction is reported by students in disadvantaged schools than advantaged schools, but in Ireland, students do not differ on the index on the basis of school socioeconomic profile (OECD, 2016c, Table II.2.27). Scores on the Inquiry-based Teaching and Learning index are not associated with increased performance in science, but they do have some association with students’ epistemic beliefs (beliefs about the nature of scientific knowledge), and also with students’ expectations for a science career at age 30, both in Ireland and across OECD countries on average (OECD, 2016c, Table II.2.27). It should be noted that the index items are related to performance in science in different ways; specifically, some items are positively associated, and others negatively associated, with performance. In Ireland, the strongest negative relationship with performance on science is for ‘students are allowed to design their own experiments’, and the strongest positive relationship is with ‘the teacher clearly explains the relevance of science concepts to our lives’ (OECD, 2016c, Table II.2.28). As these findings are correlational, they should also be interpreted with caution. However, they do indicate that responses to the individual items as presented in E-Appendix Table A6.40 should also be interpreted with reference to the contexts in which they were generated.

The fourth index, Adaption of Instruction, measures students’ perceptions of the extent to which their science teachers adapt their approach based on students’ needs, knowledge and abilities (OECD, 2016c). The index is comprised of three items; students are asked to indicate the frequency with which their science teacher 'adapts the lesson to my class's needs and knowledge', 'provides individual help when a student has difficulties understanding a topic or task', and 'changes the structure of the lesson on a topic that most students find difficult to understand' (E-Appendix Table A6.41). Ireland's score on the index does not differ significantly from the OECD average (Table 6.21). In addition, students do not differ on Adaptive Instruction based on school socioeconomic profile, either in Ireland or across OECD countries on average (OECD, 2016c, Table II.2.23). In Ireland, as well as in most PISA countries/economies, students who report that their science teachers use adaptive instruction more frequently score higher on PISA science (OECD, 2016c). A one unit increase on the index is associated with a 7.1 point increase in science score for students in Ireland, both before and after accounting for student and school socioeconomic profiles (OECD, 2016c, Table II.2.23). In Ireland, as well as across OECD countries on average, students who report that their teachers use adaptive instruction more frequently have significantly stronger epistemic beliefs and higher expectations of a science career at age 30.

The fifth index is Teacher-directed Science Instruction, which refers to the extent to which teachers provide a well-structured, clear and informative class on a topic (OECD, 2016c). The index is constructed from four items which ask students to indicate how frequently certain events happen in science class (e.g., 'the teacher explains scientific ideas' and 'the teacher discusses our questions') (E-Appendix Table A6.42). Higher scores on the index indicate a greater extent of teacher-directed science instruction reported by students. Ireland's score on the index does not differ from the OECD average (Table 6.21). According to students in Ireland, the most frequently-used teacher-directed science strategy is explaining scientific ideas (reported by 22.3% of students as occurring in every class or almost every class), and the least frequently-used is organising a whole class discussion (reported by 25.1% of students as occurring never or almost never). With the exception of organising whole class discussions, the strategies are each positively associated with performance in science (OECD, 2016c, Table II.2.18). The strategy with the strongest association with science is 'the teacher explains scientific ideas'; students who report that their teacher uses this strategy in many classes or every class score 29.1 points higher on science than other students, after accounting for the socioeconomic profile of students and schools. Overall, science scores are expected to increase by 7.0 points with a one unit increase on the Teacher-directed Science Instruction index for students in Ireland, after accounting for the socioeconomic profile of students and schools (OECD, 2016, Table II.2.17). In Ireland, and across OECD countries on average, students who report that their teachers use teacher-directed instruction more frequently have significantly stronger epistemic beliefs and higher expectations of a science career at age 30. Compared to students in disadvantaged schools, students in advantaged schools in Ireland do not report more frequent teacher-directed science instruction in their classes (OECD, 2016, Table II.2.17).

The sixth index is comprised of six items measuring students' perceived feedback from science teachers. Higher scores on Perceived Feedback indicate more frequent feedback, as reported by students. Examples of items include, 'the teacher tells me how I am performing in the course', and 'the teacher gives me feedback on my strengths in this class' (E-Appendix Table A6.43). Students in Ireland perceive the same level of feedback from science teachers as students across OECD countries on average (Table 6.21). In Ireland, and on average across OECD countries, students in disadvantaged schools report more feedback from teachers in science classes compared to students in advantaged schools (OECD, 2016c, Table II.2.20). In addition, higher levels of perceived feedback are associated with lower science scores, and, perhaps contrary to expectations, with stronger epistemic beliefs and greater expectation of a science career, in Ireland and across OECD countries on average (OECD, 2016c, Table II.2.20).

Table 6.22 summarises the correlations between indices measuring science class characteristics and achievement in science for students in Ireland.

Table 6.22. Correlations of indices measuring characteristics of science classes with science achievement, in Ireland

	Science		
	r	*t*	*p*
Disciplinary climate in science classes	**.088**	4.63	< .001
Teacher support in science class	.020	1.34	NS
Inquiry-based science teaching and learning practices	-.028	-1.22	NS
Adaptation of instruction	**.076**	5.43	< .001
Teacher directed science instruction	**.088**	5.50	< .001
Perceived feedback	**-.110**	-6.47	< .001

Significant correlations are in bold. Df=80 (number of variance strata associated with balanced repeated replication (BRR) method of variance estimation).

6.2.5. Parental involvement

This section addresses aspects of parental involvement that require contact between parents and schools, in particular, school policies for parental involvement, and parents' participation in school activities.[37] Quality contact between parents and schools can contribute to positive outcomes for students (OECD, 2016c).

Firstly, PISA asked principals if various statements about parental involvement apply to their schools; principals could respond 'yes' or 'no' (E-Appendix Table A6.44). The vast majority of principals in Ireland answered 'yes' to the statements, 'our school provides a welcoming and accepting atmosphere for parents to get involved' (100%), 'our school designs effective forms of school-to-home and home-to-school communications about school programmes and children's progress' (98.8%), 'our school includes parents in school decisions' (98.7%), and 'our school provides information and ideas for families about how to help students at home with homework and other curriculum-related activities, decisions and planning' (93.8%). Ireland's average score across the items addressing school efforts to involve parents is 97.8% (SE = 0.69%) compared to an OECD average of 88.2% (SE = 0.21%) (OECD, 2016c, Table II.3.27). However, the high levels of agreement with the statements in Ireland and across PISA countries/economies likely reflects a degree of social desirability on the part of principals (OECD, 2016c).

PISA also asked parents about the extent to which they agree or disagree with various statements about school policies for parental involvement; for example, 'my child's school involves parents in the school's decision-making process', and 'my child's school provides effective communication between the school and families' (E-Appendix Table A6.45). The majority of parents agree or strongly agree with the various statements. Indeed, almost 90% of parents agree or strongly agree with 'my child's school provides effective communication between the school and families' (89.5%), and 'my child's school provides an inviting atmosphere for parents to get involved' (89.1%). The statements with which parents disagree most are 'my child's school involves parents in the school's decision-making process' (30.8%) and 'my child's school uses community services to help support school programmes and student development' (29.6%). PISA combined the items into an index of parents' perceptions of school efforts to involve parents (School Policies for Parental Involvement), with higher scores indicating greater effort. Ireland's mean score (0.25) on the index is significantly higher than the OECD average (-0.02) (Table 6.23). This indicates that, compared to parents on

[37] A more detailed analysis of parental involvement and its relationship to student achievement in PISA 2015 will be published by the Educational Research Centre in 2017 as a separate thematic report.

average across OECD countries, parents in Ireland feel more strongly that schools try to involve them in their child's education.

Table 6.23. Mean scores on the School Polices for Parental Involvement index (parents' perspective), in Ireland, and on average across OECD countries

	Ireland			OECD 11*			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
School policies for parental involvement	0.25	(0.02)	0.98	-0.02	(0.01)	0.96	**0.27**	(0.02)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference. *OECD 11 average: 11 OECD countries of 18 PISA countries/economies that administered the parent questionnaire.

The association between parents' perceptions of school polices for parental involvement and students' achievement in science is in the weak negative range (r = -.10, t = -5.00, p < .001) and is significant. Similarly, the associations with reading and mathematics are in the weak negative range and are significant (E-Appendix Table A6.46).

PISA 2015 asked parents to report if, during the previous academic year, they had participated in any of ten different school-related activities such as 'discussed my child's progress on the initiative of their teachers', 'attended a scheduled meeting or conferences for parents', and 'volunteered in physical or extracurricular activities' (E-Appendix Table A6.47). Answers were combined to create the index, Parental Involvement in School-related Activities, which represents the number of questions or activities to which parents answered 'yes', ranging from zero activities to ten activities (OECD, 2016c). In Ireland, parents reported participating in an average of about three activities (2.96), compared to an OECD average of 3.79 (Table 6.24). In Ireland, as well as across the other OECD countries that administered the Parent Questionnaire, parents of students who attend disadvantaged schools are more likely to report having participated in school-related activities than parents of children who attend advantaged schools (OECD, 2016c, Table II.3.31).

Table 6.24. Mean scores on the index of parental involvement in school-related activities, in Ireland and on average across OECD countries

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Parental involvement in school-related activities	2.96	(0.04)	1.99	3.79	(0.01)	2.25	**-0.83**	(0.04)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference. Data were extracted from OECD (2016c), Table II.3.21. OECD 11 average (11 OECD countries of 18 PISA countries/economies that administered the parent questionnaire).

In the majority of participating countries/economies, students whose parents report greater participation in school activities score lower in science, both before and after accounting for the socioeconomic profile of students and schools (OECD, 2016c). In Ireland, this amounts to a difference of 7 score points on science after accounting for student and school socioeconomic profiles (OECD, 2016c, Table II.3.31). However, there is a positive association between parental involvement in school activities and performance in science among students whose parents indicate (by answering 'yes') that they attended 'a scheduled meeting or conferences for parents' during the previous academic year. In this instance, students in Ireland score 10 points higher on science, after accounting for socioeconomic status and the school's disciplinary climate (OECD, 2016c, Table II.3.32). A similar (10 score points) association with performance in science is observed across OECD countries on average.

6.3. Summary and Conclusion

This chapter described a range of student and school background characteristics and their relationship to achievement, with a focus on science as the major domain in PISA 2015.

Student economic, social and cultural status (ESCS) is a strong predictor of achievement in Ireland and across OECD countries, accounting for 12.7% of the variance in science achievement in Ireland and 12.9% across OECD countries on average. Among the variables that comprise the ESCS index (parent occupation, parent education and home possessions), parent occupation has the strongest association with achievement in science, reading and mathematics among students in Ireland. Students in the bottom quarter of ESCS are considered socioeconomically disadvantaged. In Ireland, students in the bottom quarter of ESCS score 80 points lower on science compared to students in the top quarter of ESCS.

A similar percentage of students in Ireland (14.4%) as across OECD countries on average (12.5%) is considered as having an immigrant background. In Ireland, there are no differences between native students and students with an immigrant background on overall science or mathematics. The only difference observed on the basis of immigrant status is on reading literacy with native students scoring some 25 points higher than immigrant students who speak a language other than English or Irish at home. It should be noted, however, that large standard errors arising from the small and dispersed numbers of students in the immigrant groups may mask differences that exist between the groups on the basis of immigrant and language background.

Students in Ireland differ in achievement based on grade level, with Transition year students outperforming students in all other grades on science, reading and mathematics. Transition year students also have higher average ESCS than students in all other grades. Third year students score higher on science than Fifth year students, but score similarly to them on reading and mathematics. In addition, students who took Higher level science for the Junior Certificate examination scored significantly higher on PISA science than students who did not study science at Junior Certificate level and those who took the examination at Ordinary level. Aspects of students' early education experiences are also related to achievement, with students who attended pre-primary education scoring higher on science, reading and mathematics compared to students who did not attend pre-primary education.

Students' participation in education is also associated with achievement. Those deemed at risk of early school leaving (12.5% of students in Ireland) score significantly lower on science than those deemed not at risk. In addition, students who skipped days at school in the two weeks before testing have significantly lower scores on all three domains than students who did not skip any days. The greatest difference across domains is observed for mathematics, with a 40.6 score point difference between students who did not skip any days and students who skipped three or more days. Arriving late for school is also associated with differences in achievement, with significantly lower scores on all domains for students who arrived late on at least one occasion in the two weeks before testing. Arriving late three or more times is associated with a score on reading literacy that is 33.5 points lower than the score of students who did not arrive late on any occasion.

Interest in ICT among students in Ireland is significantly greater than among students on average across OECD countries. Students in Ireland also feel more competent and more autonomous in their use of ICT compared to students on average across OECD countries. However, students in Ireland use ICT at school in general and outside of school for schoolwork significantly less than students across OECD countries on average. Overall, students in Ireland do not differ from students on average across OECD countries on their Use of ICT Outside of School for Leisure, but they use ICT less as a Topic of Social Interaction compared to students on average across OECD countries.

In Ireland, male and female students differ in their familiarity with, and use of, ICT. Compared to female students, male students feel more competent and autonomous with regard to ICT use. Female students report using ICT outside of school for homework more than male students. However, male students report using ICT outside of school for leisure and as a topic in social interaction more than female students. The two groups do not differ in their overall interest in ICT or in their use of ICT at school in general.

The indices of ICT familiarity and use have weak or non-existent associations with the achievement of students in Ireland in all PISA 2015 domains. This possibly reflects the low levels of engagement overall with ICT for schoolwork among students in Ireland. With regard to science, there is no association with Interest in ICT; there are weak positive, but significant, associations with Perceived Autonomy and Perceived Competence; and there are weak negative, but significant, associations with Use of ICT at School in General and Use of ICT Outside of School for Schoolwork.

Almost three-in-five (57.2%) students in Ireland, and more female students (60.5%) than male students (54%), had never taken a computer-test before PISA 2015. Students who had never taken a computer-based test before PISA 2015 have significantly lower scores on science, reading and mathematics than students who had taken a computer-based test on at least one occasion. The score point differences amount to 10.2 points for science, 9.6 points for reading literacy, and 8.8 points for mathematics. However, differences are also observed on average ESCS between students who had, and students who had not, taken a computer-based test prior to PISA 2015.

Between-school variation in performance on science accounts for 11.5% of the total variation in science performance in Ireland compared to 30.1% across OECD countries on average, and 50.0% in countries such as the Netherlands, Hungary and Bulgaria. School average ESCS is positively associated with achievement in science in Ireland; a one-unit increase in school average ESCS is associated with a science score point difference of 39 at the school level. The difference in science performance between students in advantaged and disadvantaged schools (as defined by the OECD) is 67.3 points in Ireland and 103.8 points across OECD countries on average. School average ESCS is also significantly related to performance in reading and mathematics. In Ireland, and across OECD countries on average, greater diversity in students' socioeconomic status exists among students in the same schools than among students in different schools.

With regard to school organisation, students in SSP schools under DEIS score significantly lower on science, reading and mathematics compared to students in others schools. Students in vocational schools have significantly lower scores on all domains compared to students in boys', girls' and mixed secondary schools, but do not differ significantly from students in community/ comprehensive schools. Students in vocational schools also have significantly lower ESCS than students in other schools, excluding community/comprehensive schools. Students in fee-paying schools have a mean score on science that is some 51.9 points (over half of one standard deviation) higher than students in non-fee-paying schools. Students in fee-paying schools also outperform students in non-fee-paying schools on reading and mathematics. No differences exist between students on science or reading based on the location of their school. However, students in city schools score higher on mathematics than students in schools located in towns. Students in city schools also have higher average ESCS than students in schools outside cities.

With regard to aspects of school climate that hinder learning, principals in Ireland identified truancy as the most common student factor (behaviour), and staff resistance to change as the most common teacher factor (behaviour). Ireland does not differ from OECD countries on average with regard to the extent to which principals report overall that student or teacher factors hinder learning. Scores on the Student Factors index have a weak negative, but significant, association with achievement in science, reading and mathematics, but scores on the Teacher Factors index are not significantly related to achievement in any domain.

Students in Ireland report a better disciplinary climate in science classes and more support from teachers in science classes compared to their OECD counterparts on average. However, students in Ireland do not differ from students across OECD countries on average in terms of their perceptions of the frequency of specific teaching practices (adaptive instruction, inquiry-based instruction, and teacher-directed science instruction) and the amount of feedback given by teachers in science class. A better disciplinary climate is associated with higher average performance in science, and in Ireland, this amounts to 7 score points when school and student ESCS are taken into account. Adaptive Instruction and Teacher-directed Science Instruction also have positive associations with performance in science, while Perceived Feedback has a negative association. Aspects of inquiry-based teaching and learning (e.g., the teacher clearly explaining the relevance of science concepts to students' lives) have positive associations with performance, while other aspects (e.g., students being allowed to design their own experiments) have negative associations. However, these findings are correlational, and so should be interpreted with caution. Higher frequencies of the specific teaching practices in science class and greater feedback in science class (as reported by students) are associated with stronger epistemic beliefs about science among students and higher expectations of a science career at age 30.

Parents are key stakeholders in students' education and their involvement in schools can impact on outcomes for students. Principals in Ireland report a high degree of effort by schools to involve parents. Parents also report a high degree of effort on the part of schools, particularly in the area of effective communication between schools and families, and schools providing an inviting atmosphere for parents. However, almost one third of parents disagree that their child's school involves parents in the school decision-making process. Compared to OECD countries on average, parents in Ireland report greater efforts by schools to involve parents. Parents in Ireland also report less participation in school-related activities than parents on average across OECD countries. However, participation in some school-related activities, such as discussing a child's progress on the initiative of their teacher, is negatively associated with achievement – students whose parents report more participation tend to score lower on science before and after accounting for student and school ESCS. An exception to this is participation in 'a scheduled meeting or conference for parents', which is associated with a 10 point advantage on science for students of participating parents relative to non-participating parents.

In conclusion, this chapter has provided an insight into some of the key characteristics of students and schools that can impact on achievement. These factors will be explored in further detail in specific thematic reports using national and international data from PISA 2015.

Chapter 7: Students' Engagement, Motivation and Attitudes towards Science in PISA 2015

The focus of this chapter is on students' engagement with science, their attitudes towards science and their motivations for science learning. Central to the PISA definition of science literacy is the recognition that students' attitudes towards science impact on their engagement with science (OECD, 2016a). Students' attitudes and engagement are identified as potentially important influences on their later career choices. PISA is interested in what influences students to learn science, whether they enjoy science, and the extent to which they engage in science-related activities inside and outside of school. PISA is also interested in whether or not students envisage having a future career in a science occupation and if they consider school science as necessary for their future career plans.

In this chapter, students' engagement with science is described through examining students' career aspirations, intentions to study Leaving Certificate-level science and participation in science-related activities. Next, findings relating to students' motivation for learning science are presented. Finally, aspects of students' science self-beliefs and beliefs about science are examined. Data were gathered from students via items presented in the PISA Student Questionnaire, some of which were grouped into indices and scaled to have an OECD mean of 0 and a standard deviation of 1. Supplementary figures and tables are presented in the PISA 2015 E-Appendix, available at www.erc.ie/pisa.

7.1. Science Engagement

In PISA 2015, students' engagement with science was determined by asking questions about their career expectations, their intentions to study science to Leaving Certificate level, and their participation in various science-related activities.

7.1.1. Science-related careers at age 30

PISA 2015 included an indicator of students' science career expectations at age 30, generated by asking students 'what kind of job' they expect to have at about 30 years of age. *Science career expectations* are defined as 'those career expectations whose realisation requires the study of science beyond compulsory education, typically in formal tertiary education' (OECD, 2016b, p. 111). Students entered free text responses which were later coded using the International Standard Classification of Occupations 2008 edition. Science careers were grouped into four major categories: science and engineering professionals (e.g., engineer, architect, physicist, or astronomer); health professionals (e.g., medical doctor, nurse, veterinarian, or physiotherapist); information and communications technology (ICT) professionals (e.g., software developer, or applications programmer); and science technicians and associate professionals (e.g., electrical or telecommunications engineering technician).

In Ireland, 27.3% of students expect to have a science-related career at age 30, while 59.6% expect to work in other occupations (Table 7.1). In comparison, across OECD countries on average, 24.5% of students expect to work in science-related occupation at age 30, while 56.7% expect to work in other occupations not related to science. In Ireland, the majority of students have some idea about their future occupation, with just 13.1% undecided. Across OECD countries on average, some 18.8% of students are undecided about their future careers.

Table 7.1. Percentages of students in Ireland and on average across OECD countries who intend to have science-related or other careers at age 30

	Ireland		OECD	
	%	SE	%	SE
Expects science career	27.3	0.70	24.5	(0.13)
Expects other occupation	59.6	0.80	56.7	(0.15)
Vague, do not know, undecided etc*	13.1	0.62	18.8	(0.11)

*This includes students with vague career expectations, students who do not know, or are undecided about a career, and students whose answer is missing. It excludes those who skipped or did not reach the question (OECD, 2016b). OECD data were extracted from OECD (2016b), Tables I.3.10a and I.3.10b.

OECD countries with the highest percentages of students expecting a career in science include Mexico (40.7%), the United States (38.0%), and Chile (37.9%). OECD countries with the lowest percentages include Denmark (14.8%), Germany (15.3%), the Netherlands (16.3%), and Finland (17.0%) (OECD, 2016b, Table 1.3.10b).

In Ireland, 28.0% of male students and 26.6% of female students envisage a career in science (Table 7.2). Similarly, across OECD countries on average, roughly equivalent percentages of male students (25.0%) and female students (23.9%) expect a science career. The percentages of students in Ireland expecting a career in science and expecting careers in other occupations not related to science are presented in the E-Appendix Tables A7.1 to A7.3 by school SSP (DEIS) status, students' immigrant and language background, and school type.

Table 7.2. Percentages of students who intend to have science-related careers by about age 30, by gender, in Ireland and on average across OECD countries

	Science Careers			
	Males		Females	
	%	SE	%	SE
Ireland	28.0	(0.87)	26.6	(0.97)
OECD	25.0	(0.17)	23.9	(0.16)

OECD data were extracted from OECD (2016b), Table 1.3.10b.

Each of the four science career types was chosen by a broadly similar percentage of students in Ireland and on average across OECD countries (Table 7.3). Slightly greater percentages of students in Ireland envisage a career in a health profession (13.8%) and in ICT (3.4%) compared to students on average across OECD countries (11.6% for health professions and 2.6% for ICT).

Table 7.3. Percentages of students expecting a science career at age 30 by science career type, in Ireland and on average across OECD countries

	Ireland		OECD	
	%	SE	%	SE
Science and engineering professionals	8.8	(0.41)	8.8	(0.08)
Health professionals	13.8	(0.56)	11.6	(0.09)
ICT professionals	3.4	(0.27)	2.6	(0.04)
Science-related technicians and associate professionals	1.3	(0.15)	1.5	(0.03)

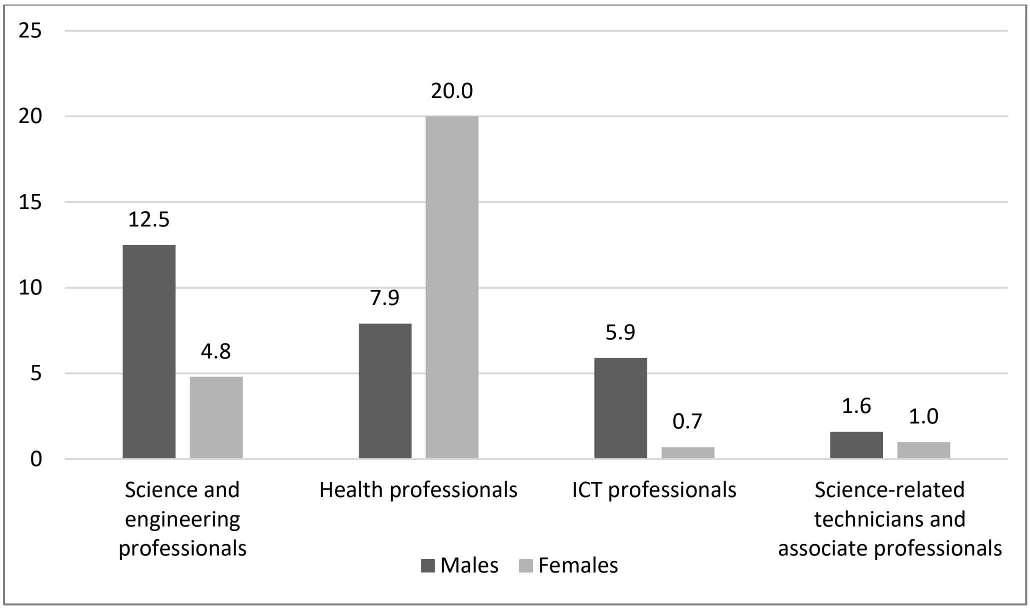
OECD data were extracted from OECD (2016b), Table 1.310a.

In Ireland, careers in health professions are the most popular science career choice (Table 7.3). For students in Ireland seeking a career as a health professional, nursing, physiotherapy and medicine are the top three choices (see Insert 7.1). Health professions are also considerably more popular among female students (20.0%) than among male students (7.9%) (Figure 7.1).

Insert 7.1. Top 10 science-related career categories chosen by students in Ireland

Nursing professional
Physiotherapist
Generalist medical practitioner
Engineering professional (excluding electrotechnology)
Veterinarian
Science and engineering professional
Specialist medical practitioner
Software developer
Biologists, botanists, zoologists and related professionals
Information and communications technology professionals

Figure 7.1. Percentages of students expecting a career in science by science career category and gender, in Ireland



See E-Appendix Tables A7.4 to A7.5 for the percentages of students expecting a science career at age 30 by science career category and gender, in Ireland, and across OECD countries on average.

The second most popular career type among students in Ireland is science and engineering, chosen by 8.8% of students (Table 7.3), and by more male students (12.5%) than female students (4.8%) (Figure 7.1). Indeed, males are more than twice as likely as females to envisage a career as a science or engineering professional. Careers as ICT professionals (e.g., software developer, or applications programmer) are chosen by 3.4% of students in Ireland, and also by considerably more male (5.9%) than female (0.7%) students. The least popular science careers are science-related technicians and associate professionals (e.g., electrical or telecommunications engineering technician), selected by 1.3% of students in Ireland (1.6% males and 1.0% females) and 1.5% across OECD countries on average (2.1% males and 0.8% females) (E-Appendix Table A7.5).

In almost all PISA countries/economies, the expectation of pursuing a career in science is strongly related to the proficiency level attained in PISA science (OECD, 2016b). In Ireland, 45.7% (SE = 3.33) of the top performers in science (Proficiency Level 5 and above) expect to be in a science-related career at 30, compared to 14.1% (SE = 1.52) of the low performers in science (those performing below Proficiency Level 2) (OECD, 2016b, Table I.3.10b). Similarly, across OECD countries on average, 13.3% (SE = 0.21) of low performers and 41.7% (SE = 0.59) of top performers expect a science career. The top performers in science in Ireland, and on average across OECD countries, are significantly more likely to envisage a career in science than are students performing below Level 5. Among the top performers in science in Ireland (Level 5 and above), a similar percentage of male students (46.6%, SE = 3.89) as female students (43.8%, SE = 6.00) expects a career in science at age 30 (OECD, 2016b, Table I.3.10c).

Students with at least one parent educated to third level are significantly more likely to expect a career in science at age 30 than their counterparts who do not have a tertiary-educated parent, both in Ireland and across OECD countries on average (OECD, 2016b, Table I.3.10b).

Students in Ireland who expect to be working in a science career at age 30 have a significantly higher mean score on overall science (532.5) than students expecting a career in a field that is not science-related (490.3) (Table 7.4). The difference in mean science scores between those expecting a science career and those expecting a career in a different field amounts to 41.3 scale score points. Similarly, large significant differences in overall science performance are found between male students expecting and not expecting a career in science (48.7 points), and between female students expecting and not expecting a career in science (34.6 points) (Tables 7.5 and 7.6).

Table 7.4. Mean science scores by science career expectations, in Ireland

	Expects science career at age 30		Expects other occupation		Difference (SED)
	Mean	SE	Mean	SE	
Overall science performance	532.5	(3.09)	490.3	(2.55)	**41.3** (4.01)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

Table 7.5. Mean science scores by science career expectations for male students, in Ireland

	Males				
	Expects science career at age 30		Expects other occupation		Difference
	Mean	SE	Mean	SE	(SED)
Overall science performance	542.5	(3.54)	493.8	(3.52)	**48.7** (4.99)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

Table 7.6. Mean science scores by science career expectations for female students, in Ireland

	Females				
	Expects science career at age 30		Expects other occupation		Difference
	Mean	SE	Mean	SE	(SED)
Overall science performance	521.5	(4.42)	486.9	(2.86)	**34.6** (5.26)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

7.1.2. Students' intentions to study a science subject at Leaving Certificate level

PISA 2015 asked students in Ireland about their intentions to study any science subject at Leaving Certificate level. Physics, Biology, Chemistry, Physics/Chemistry combined, and Agricultural Science are science subjects offered at Leaving Certificate level in Ireland. The majority (82.6%) of Irish 15-year-olds who participated in PISA 2015 reported either studying, or intending to study, a science subject for the Leaving Certificate (Table 7.7). A larger percentage of female students (85.3%) than male students (80.0%) reported studying or intending to study a science subject at Leaving Certificate level.

Table 7.7. Percentages of students studying or intending to study a science subject at Leaving Certificate level overall and by gender, in Ireland

	All		Males		Females	
	%	SE	%	SE	%	SE
Intending to study a science subject at Leaving Certificate level	82.6	(0.97)	80.0	(1.07)	85.3	(1.28)
Not intending to study a science subject at Leaving Certificate level	17.4	(0.97)	20.0	(1.07)	14.7	(1.28)

See E-Appendix Tables A7.6 to A7.8 for students' intentions to study science at Leaving Certificate level by school SSP (DEIS) status, students' immigrant and language background, and school type.

PISA 2015 also asked students to indicate whether a range of factors are not important, somewhat important, quite important, or very important in their decision to study a science subject(s) for the Leaving Certificate. The 14 factors included 'availability of the science subjects I want to study', 'the career(s) I am interested in', 'the third-level course I want to study', and 'advice from teachers in my school'. Among those studying or intending to study a science subject at Leaving Certificate level, the factors most often rated as 'very important' are those relating to students' career interests (52.8%), third-level course of choice (44.9%), and interest in Leaving Certificate science subjects (40.2%) (E-Appendix Table A7.9).

7.1.3. Students' participation in science-related activities

PISA 2015 asked students to indicate how often they engage in a range of science-related activities at or outside of school. The nine activities include 'watching television programmes about science', 'visiting websites about science topics', 'attending a science club', and 'simulating technical processes in computer programs/virtual labs'. Students were asked to indicate if they engage in these activities very often, regularly, sometimes, or never or hardly ever. Table 7.8 presents the percentages of students in Ireland and on average across OECD countries who report participating in the science-related activities very often or regularly (also see E-Appendix Table A7.10).

In Ireland, as well as across OECD countries on average, a relatively small percentage of students reports engaging in each of the science-related activities listed (Table 7.8). The most common activity engaged in very often or regularly by students in Ireland is 'watch TV programmes about science' (16.8%), followed by 'visit web sites about science topics' (14.4%), and 'follow news of science, environmental, or ecology organisations via blogs and microblogging' (13.1%). Indeed, students in Ireland more often engage with science through television and the Internet than through books or magazines. Less than 10% of Ireland's 15-year-olds reported borrowing or buying books on science (6.3%), or reading science magazines or science articles in newspapers (8.5%). Students across OECD countries on average also engage with science more often online and through television, than through books or magazines. However, as Table 7.8 shows, students in OECD countries on average report engaging with each of the nine science activities more frequently than do students in Ireland. The greatest difference between students in Ireland and in OECD countries on average was observed for the item 'read science magazines or science articles in newspapers', for which the percentage of students in Ireland (8.5%) is nearly half that of OECD countries on average (15.8%). Among students in Ireland, the least common activity undertaken very often or regularly is attending a science club, which is reported by 1.6% of students in Ireland, in comparison to 8.3% of students on average across OECD countries.

Table 7.8. Percentages of students participating in science activities *very often or regularly,* in Ireland and on average across OECD countries

	Ireland		OECD	
	%	SE	%	SE
Watch TV programmes about science	16.8	(0.54)	23.0	(0.11)
Borrow or buy books on science topics	6.3	(0.33)	11.1	(0.09)
Visit web sites about science topics	14.4	(0.55)	19.1	(0.11)
Read science magazines or science articles in newspapers	8.5	(0.41)	15.8	(0.10)
Attend a science club	1.6	(0.17)	8.3	(0.09)
Simulate natural phenomena in computer programs\virtual labs	5.8	(0.32)	9.6	(0.09)
Simulate technical processes in computer programs\virtual labs	6.5	(0.35)	9.9	(0.09)
Visit web sites of ecology organisations	4.8	(0.29)	11.2	(0.09)
Follow news of science, environmental, or ecology organizations via blogs or news websites	13.1	(0.45)	14.6	(0.10)

OECD data were extracted from OECD (2016b), Table I.3.5a.

Greater percentages of male students than female students report participating in each of the science activities regularly or very often, both in Ireland (Table 7.9) and on average across OECD countries (OECD, 2016b (web-based), Table I.3.5c). All gender differences are significant among students in Ireland and on average across OECD countries, with the exception of the item 'visit web sites of ecology organisations', where the gender difference in Ireland is not statistically significant (Table 7.9). The biggest difference between male and female students in Ireland is on watching television programmes about science (a difference of 9.8% in favour of males). Similarly, across the OECD countries on average, the biggest gender difference relates to watching television programmes about science (a difference of 13.3%).

Table 7.9. Percentages of students participating in science activities *very often or regularly,* by gender, in Ireland

	Males		Females		Difference	
	%	SE	%	SE	M-F	SE
Watch TV programmes about science	21.7	(0.74)	11.9	(0.67)	**9.8**	(0.93)
Borrow or buy books on science topics	7.5	(0.47)	5.1	(0.47)	**2.5**	(0.67)
Visit web sites about science topics	17.4	(0.80)	11.4	(0.66)	**6.0**	(0.99)
Read science magazines or science articles in newspapers	10.9	(0.67)	6.1	(0.53)	**4.8**	(0.90)
Attend a science club	2.2	(0.30)	0.9	(0.16)	**1.3**	(0.36)
Simulate natural phenomena in computer programs\virtual labs	8.7	(0.53)	2.9	(0.33)	**5.8**	(0.63)
Simulate technical processes in computer programs\virtual labs	10.2	(0.65)	2.8	(0.33)	**7.4**	(0.77)
Visit web sites of ecology organisations	5.2	(0.41)	4.3	(0.40)	1.0	(0.56)
Follow news via blogs and microblogging	16.9	(0.64)	9.1	(0.60)	**7.8**	(0.85)

The percentages of students participating in science activities *very often or regularly* and *sometimes or never or hardly ever,* by gender in Ireland are presented in E-Appendix Table A7.11.

Students' responses to the items about participation in science activities were also used to construct an index of Engagement with Science Activities, with higher values indicating more frequent participation. Ireland has a mean score of -0.37 on the Science Activities index, which is significantly lower than the mean score for OECD countries on average (-0.01) (Table 7.10). High scoring OECD countries on this index include Turkey (0.68), Mexico (0.53) and Poland (0.40) (OECD, 2016b, Table I.3.5b). OECD countries scoring lower than Ireland include Japan (-0.57), Finland (-0.50), and the Netherlands (-0.43).

Table 7.10. Mean scores on the Science Activities index, in Ireland and across OECD countries on average

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Engagement with science activities	-0.37	(0.02)	1.07	-0.01	(0.00)	1.10	**-0.36**	(0.02)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

In Ireland, male students have a significantly higher mean score than female students on the Science Activities index (-0.20 for males versus -0.55 for females), meaning 15-year-old males engage more frequently in science activities than 15-year-old females (Table 7.11). In addition, students in girls' secondary schools score significantly lower on the Science Activities index than do students in boys' secondary schools (-0.46 for girls' versus -0.17 for boys) (E-Appendix Table A7.12).

Mean scores on the Science Activities index are reported by school type, school SSP (DEIS) status and students' immigrant and language background in Ireland in E-Appendix Tables A7.12 to A7.14.

Table 7.11. Mean scores on the Science Activities index, by gender, in Ireland

	Males		Females		Difference	
	Mean	SE	Mean	SE	M-F	SED
Engagement with science activities	-0.20	(0.02)	-0.55	(0.02)	**0.35**	(0.03)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

A significant positive correlation in the moderate range (.31) is observed between scores on the Science Activities index and achievement in overall science for all students in Ireland and for students at each grade level (Second year through Fifth year, including Transition year) in Ireland (Table 7.12). Hence, frequency of engagement with science activities is associated with higher performance on PISA science among all students in Ireland, and among students in Ireland at all grade levels represented in PISA.

Table 7.12. Correlations of science achievement with engagement in science activities by grade level, in Ireland

	Science		
Science Activities	*r*	*t*	*p*
All	**.31**	15.5	< .001
Second	**.36**	3.0	< .001
Third	**.30**	15.0	< .001
Transition	**.35**	11.67	< .001
Fifth	**.36**	7.2	< .001

Significant correlations are in bold. Df=80 (number of variance strata associated with balanced repeated replication (BRR) method of variance estimation).

In Ireland, students in the top quarter of the Science Activities index have a mean score on the overall science scale (538.8) that is significantly higher than the score of students in the bottom quarter of the index (460.9) (Table 7.13). Indeed, the difference in science performance between the 25% of students who participate the most in science activities and the 25% of students who participate the least in science activities is 77.9 score points. The expected change in overall science performance resulting from an increase of one standard deviation on the Science Activities index is 25.8 scale score points in Ireland and 5.0 points across OECD countries on average.

Table 7.13. Mean scores in science of students in the top and bottom quarters of the Science Activities index, and association between engagement in science-related activities and overall science performance, in Ireland

	Science Activities			
	Mean science score		Diff: Top-Bottom (SED)	Assoc w/index* (SE)
	Bottom Q index	Top Q index		
Ireland	460.9 (3.02)	538.8 (3.58)	**77.9** (3.61)	25.8 (1.34)
OECD	475.8 (0.56)	489.1 (0.77)	**13.3** (0.84)	5.0 (0.27)

Associations are statistically significant ($p < .05$). SE = standard error of the mean; SED = standard error of the difference. * Indicates increase in science achievement corresponding with an increase of one standard deviation on the index. Data were extracted from OECD (2016b), Table I.3.5b.

7.2. Motivation for Science Learning

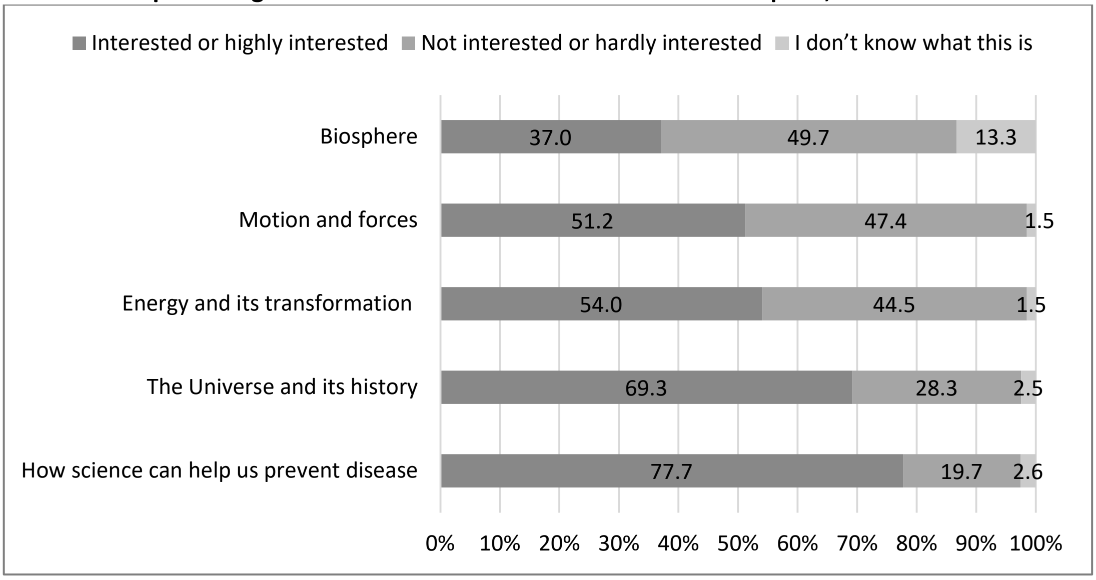
Students' engagement with science activities, choice of science subjects at school, and aspirations for science careers, are affected by their motivations for learning science (OECD, 2016b). In PISA 2015, two forms of motivation to learn science are distinguished. Firstly, students might learn science because they enjoy science and find learning it interesting and fun (intrinsic motivation). Such students might be interested in science in a general sense, or might be interested in specific aspects of science, such as a particular discipline (e.g., physics or biology) or research area (e.g., the prevention of disease). Secondly, students might learn science because it is useful for their future study and/or career plans (instrumental motivation). Some students will be motivated to learn science out of interest and enjoyment and also because it will help them achieve their future goals. Hence PISA 2015 assessed students' intrinsic and instrumental motivation to learn science, as well as their interest in broad science topics.

To assess students' intrinsic motivation to learn science, PISA asked students the extent to which they agree or disagree with various statements about their enjoyment of doing and learning science. The majority of students in Ireland agreed or strongly agreed that they 'enjoy learning new things in science' (78.0%), are 'interested in learning about science' (73.8%), and are 'happy working on science topics' (70.8%). Students agreed least with the statement 'I like reading about science' (56.1%), followed by the statement, "I generally have fun when I am learning science topics" (64.3%) (E-Appendix Table A7.15).

PISA also asked students about the extent to which they are interested in five science topics: 'the biosphere' (e.g., ecosystems and sustainability), 'motion and forces' (e.g., velocity, friction, magnetic and gravitational forces)', 'energy and its transformation' (e.g. conservation, chemical reactions), 'the Universe and its history', and 'how science can help us prevent disease'. Students in Ireland were most interested in how science can help us prevent disease (77.7%), followed by the Universe and its history (69.3%), and least interested in the biosphere (49.7%) and motion and forces (47.4%) (Figure 7.2). Thirteen percent of students in Ireland reported that they do not know what the biosphere is (E-Appendix Table A7.16).

A similar pattern of responses is observed across the OECD countries on average, with the greatest interest reported for how science can help us prevent disease (66.2%), and the Universe and its history (65.9%), and the least for the biosphere (40.9%) (OECD, 2016b, Table I.3.2a). However, across the OECD countries on average, a considerably smaller percentage of students (3.4%) reported not knowing what the biosphere is, compared to Ireland (13.3%).

Figure 7.2. Percentages of students interested in, and not interested in, various science topics, and the percentages of students who do not know what each topic is, in Ireland



In Ireland (E-Appendix Table A7.17), and across OECD countries on average (OECD, 2016b (web-based), Table I.3.2c), more male students than female students are interested or highly interested in the biosphere, motion and forces, energy and its transformation, and the Universe and its history. On the other hand, more female students than male students are interested or highly interested in 'how science can help us prevent disease', both in Ireland and on average across OECD countries.

Students' instrumental motivation to learn science was assessed by asking them to indicate their level of agreement with four statements about how useful they perceive science learning to be for their future study and career plans. Over three-quarters of students in Ireland agreed or strongly agreed with the statements 'making an effort in my science subject(s) is worth it because this will help me in the work I want to do later on' (78.1%), and 'studying science subject(s) is worthwhile for me because what I learn will improve my career prospects' (76.4%) (E-Appendix Table A7.18). More than two-thirds of students in Ireland agreed or strongly agreed with the statements, 'what I learn in my science subject(s) is important for me because I need it for what I want to do later on' (67.8%), and 'many things I learn in my science subject(s) will help me to get job' (73.1%).

Using responses to the items addressing intrinsic and instrumental motivation, PISA constructed two indices of motivation for science learning: Enjoyment of Science and Instrumental Motivation. For both scales, higher scores indicate higher levels of motivation for science learning. Another index, Interest in Science Topics, was similarly constructed from the relevant items, with higher scores indicating greater interest in science.

Table 7.14 presents mean scores, standard errors and standard deviations for the three scales relating to motivation to learn science (Enjoyment of Science, Instrumental Motivation, and Interest in Science Topics). Ireland scores significantly above the OECD average on all three scales, with mean scores of 0.20 for Enjoyment of Science, 0.36 for Instrumental Motivation, and 0.06 for Interest in Science Topics.

Table 7.14. Mean scores on Enjoyment of Science, Instrumental Motivation, and Interest in Science Topics in Ireland, and on average across OECD countries

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Enjoyment of science	0.20	(0.02)	1.10	0.02	(0.00)	1.11	**0.18**	(0.02)
Instrumental motivation	0.36	(0.02)	0.98	0.13	(0.00)	0.98	**0.23**	(0.02)
Interest in science topics	0.06	(0.02)	0.94	0.00	(0.00)	0.98	**0.06**	(0.02)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

Ireland scores similarly on Enjoyment of Science as New Zealand (0.20) (OECD, 2016b, Table I.3.1a). Highest scoring OECD countries on Enjoyment of Science include Canada (0.40) and Portugal (0.32), and lowest scoring countries include the Netherlands (-0.52) and Slovenia (-0.36). Ireland scores the same on Instrumental Motivation as Portugal (OECD, 2016b, Table I.3.3a). OECD countries scoring highest on Instrumental Motivation include Mexico (0.53) and Canada (0.46), and countries scoring lowest include Germany (-0.24) and Austria (-0.22). Ireland's mean score on the Interest in Science Topics scale is similar to those of Belgium (0.07), the United States (0.05), and Norway (0.05) (OECD, 2016, Table I.3.2a). OECD countries scoring highest on this scale include Mexico (0.43), Portugal (0.27) Canada (0.26), while the lowest scoring include the Czech Republic (-0.67) and Slovenia (-0.32).

Male students in Ireland score significantly higher on Enjoyment of Science (0.25) and Interest in Science Topics (0.16) than do female students (0.15 and -0.05 respectively) (Table 7.15). However, male students (0.34) and female students (0.39) in Ireland do not differ significantly in their Instrumental Motivation to learn science. Significant gender differences also exist on all three scales across OECD countries on average.

Table 7.15 Mean scores on Enjoyment of Science, Instrumental Motivation, and Interest in Science Topics by gender, in Ireland and on average across OECD countries

	Ireland			OECD		
	Males	Females	Diff	Males	Females	Diff
	Mean (SE)	Mean (SE)	M-F (SED)	Mean (SE)	Mean (SE)	M-F (SED)
Enjoyment of science	0.25	0.15	**0.10**	0.08	-0.05	**0.13**
	(0.02)	(0.03)	(0.04)	(0.00)	(0.00)	(0.01)
Instrumental motivation	0.34	0.39	-0.05	0.16	0.12	**0.04**
	(0.02)	(0.03)	(0.04)	(0.00)	(0.00)	(0.01)
Interest in science topics	0.16	-0.05	**0.21**	0.12	-0.11	**0.23**
	(0.02)	(0.02)	(0.03)	(0.00)	(0.00)	(0.00)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference. OECD data were extracted from OECD (2016b, web-based), Tables I.3.1c, I.3.2c and I.3.3c.

Comparing students' motivations to study science by school type shows that students in girls' secondary schools in Ireland score significantly higher (0.45) on Instrumental Motivation compared to students in boys' secondary schools (0.31) and students in vocational schools (0.31) (E-Appendix Table A7.19). However, students in girls' secondary schools score significantly lower (0.06) than students in boys' secondary schools (0.21) on Interest in Science Topics. The mean scores of students in SSP schools on Enjoyment of Science (0.08) and Interest in Science Topics (-0.09) are significantly lower than those of students in non-SSP schools (0.22 and 0.09 respectively) (E-Appendix Table A7.20). Students in non-SSP schools score slightly higher on Instrumental Motivation than students in SSP schools, but the difference is not significant.

Native students in Ireland score significantly lower on Enjoyment of Science (0.18) than immigrant students who speak English or Irish at home (0.33) and immigrant students who speak other languages at home (0.42), and score significantly lower on Interest in Science Topics (0.05) than immigrant students who speak other languages (0.19) (E-Appendix Table A7.21). Native students do not differ from immigrant students who speak English or Irish, or immigrant students who speak other languages, in terms of Instrumental Motivation to learn science.

Enjoyment of science and interest in science topics are positively related to performance in science, with significant correlations in the moderate range (.39 for both) (Table 7.15). A weak-to-moderate relationship exists between instrumental motivation for science learning and science performance (.20) (Table 7.16).

Table 7.16. Correlations of Enjoyment of Science, Instrumental Motivation, and Interest in Science Topics with performance in science, in Ireland

	Science		
	r	*t*	*p*
Enjoyment of science	**.391**	3.00	<.001
Instrumental motivation	**.197**	14.07	<.001
Interest in science topics	**.389**	32.42	<.001

Significant correlations are in bold. Df=80 (number of variance strata associated with balanced repeated replication (BRR) method of variance estimation).

For each of the three motivation indices (Enjoyment of Science, Instrumental Motivation, and Interest in Science Topics), students scoring in the top quarter have a mean score on overall science that is significantly higher than students in the bottom quarter of the index (Table 7.17).

Table 7.17. Mean scores on science of students in the top and bottom quarters of the Enjoyment of Science, Instrumental Motivation, and Interest in Science Topics indices, and associations with overall science performance, in Ireland and on average across OECD countries

	Ireland			
	Mean science score		Diff: Top-Bottom (SED)	Assoc w/index* (SE)
	Bottom Q index (SE)	Top Q index (SE)		
Enjoyment of science	485.4 (3.36)	553.0 (3.21)	**94.6** (3.94)	**31.5** (1.09)
Instrumental motivation	487.8 (4.78)	532.0 (3.02)	**44.2** (4.82)	**18.1** (1.26)
Interest in science topics	457.7 (4.11)	552.6 (3.06)	**94.9** (4.13)	**37.0** (1.14)
	OECD			
	Mean science score		Diff: Top-Bottom (SED)	Assoc w/index* (SE)
	Bottom Q index (SE)	Top Q index (SE)		
Enjoyment of science	462.9 (0.57)	537.7 (0.66)	**74.8** (0.76)	**25.2** (0.23)
Instrumental motivation	492.7 (0.57)	518.0 (0.66)	**25.3** (0.76)	**9.3** (0.27)
Interest in science topics	495.7 (0.58)	532.3 (0.65)	**65.5** (0.76)	**25.3** (0.26)

Values in bold are statistically significant. SE = standard error of the mean; SED = standard error of the difference.
* Indicates increase in science achievement corresponding with an increase of one standard deviation on the index. OECD data were extracted from OECD (2016b), Tables I.3.1b, I.3.2b and I.3.3b.

In Ireland, the difference in science performance between the 25% of students who enjoy science most and the 25% of students who enjoy science least is 94.6 score points (Table 7.17). Similarly, the difference in science performance between the students who are most and least interested in science topics is 94.9 score points. The expected change in overall science performance resulting from a one standard deviation increase is 31.5 score points for the Enjoyment of Science scale and 37.0 score points for the Interest in Science Topics scale. For Instrumental Motivation, the difference between students with mean scores in the top and bottom quarters is 44.2 score points. With a one standard deviation increase on this scale, students' scores are expected to increase by 18.1 score points.

In Ireland, 15.5% of the variation in science performance is explained by enjoyment of science, compared to 9.1% across OECD countries on average (OECD, 2016b, Table I.3.1b). Similarly, interest in science topics accounts for 15.5% of the variation in science performance in Ireland, compared to 7.7% on average across OECD countries (OECD, 2016b, Table I.3.2b). Finally, instrumental motivation to learn science accounts for 4.0% of the variation in science performance in Ireland and 1.4% across OECD countries on average (OECD, 2016b, Table I.3.3b).

7.3. Science Self Beliefs

Students' engagement with science is also associated with their beliefs about their own strengths and abilities in science (OECD, 2016b). In PISA 2015, students' *science self-efficacy* is defined as 'the extent to which students believe in their own ability to handle science tasks effectively and overcome difficulties' (OECD, 2016b, p. 111).

Science self-efficacy was assessed by asking students about their perceived ability to use their knowledge of science to complete real world science tasks such as recognising the scientific issue or question that underlies a newspaper report on a health issue. For each task, students were asked to indicate the confidence with which they could complete the task by selecting 'could do easily', 'could do this with a bit of effort', 'would struggle to do this on [their] own', or 'couldn't do this'. In Ireland, students most often reported 'I can do easily' (48.8%) and least often reported 'I couldn't do this' (4.0%), to the task, 'explain why earth quakes occur more frequently in some areas than in others' (E-Appendix Table A7.22). Students least often reported 'I could easily do this' (13.9%), and most often reported 'I couldn't do this' (21.1%) to the task 'discuss how new evidence can lead you to change your understanding about the possibility of life on Mars' (13.9%) (E-Appendix Table A7.22).

A greater percentage of male students than female students feel that they can easily 'recognise the scientific issue or question that underlies a newspaper report on a health issues', 'explain why earthquakes occur more frequently on some areas than others', 'predict how changes in the environment will affect the survival of certain species', and 'discuss how evidence can lead you to change your understanding about the possibility of life on Mars' (E-Appendix Table A7.23). Similar percentages of male and female students have confidence in 'easily' describing 'the role of antibiotics in the treatment of disease', 'identifying the scientific issues and questions associated with the disposal of rubbish', and identifying 'the better of two explanations for the formation of acid rain'. Slightly more female students than male students feel they could 'easily' 'interpret the scientific information provided on the labelling of food items'.

Using students' responses to the eight science task items, PISA constructed an index of science self-efficacy, with higher scores reflecting a higher belief in one's ability to effectively use one's knowledge of science in real world situations. Mean scores on the Science Self-Efficacy index for Ireland and for OECD countries on average are presented in Table 7.18. Students in Ireland have a mean score (0.06) on Science Self-Efficacy that is higher than the mean score of students on average across OECD countries (0.04), but not significantly so.

Table 7.18. Mean scores on the Science Self-Efficacy index, in Ireland and on average across OECD countries

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Science self-efficacy	0.06	(0.02)	1.20	0.04	(0.00)	1.22	0.02	(0.02)

Significant differences in are in bold. SE = standard error of the mean; SED = standard error of the difference.

OECD countries scoring similarly to Ireland on Science Self-Efficacy are Slovenia (0.07), Australia (0.07), and Sweden (0.05). OECD countries scoring highest on Science Self-Efficacy include Canada (0.35) and Turkey (0.35). Countries scoring lowest on the index include Japan (-0.46) and Spain (-0.14) (OECD, 2016b, Table I.3.4a). Male students score significantly higher on Science Self-Efficacy than female students in Ireland (0.18 for males compared to -0.06 for females) (Table 7.19), as well as across OECD countries on average.

Table 7.19. Mean scores on the Science Self-Efficacy index by gender, in Ireland and on average across OECD countries

	Science self-efficacy					
	Males		Females		Difference	
	Mean	SE	Mean	SE	M-F	SED
Ireland	0.18	(0.02)	-0.06	(0.03)	**0.24**	(0.04)
OECD	0.14	(0.00)	-0.06	(0.00)	**0.20**	(0.01)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference. OECD data were extracted from OECD (2016b, web-based), Table I.3.4c.

In Ireland, students in girls' secondary schools score significantly lower on Science Self-Efficacy than students in boys' secondary schools (-0.06 for girls' schools and 0.18 for boys' schools), but do not score differently to students in mixed, vocational, or community/comprehensive schools (E-Appendix Table A7.24). Native students have a lower mean score on Science Self Efficacy (0.05) than immigrant students who speak English or Irish (0.16), and immigrant students who speak other languages at home (0.11), but the differences are not significant (E-Appendix Table A7.25). Students in schools in the SSP score significantly lower on Science Self-Efficacy (-0.14) than do students in non-SSP schools (0.10) (E-Appendix Table A7.26).

A significant positive correlation in the moderate range (r = .371, t = 28.54, p < .001) is observed between science self-efficacy and performance in science among students in Ireland, meaning students' beliefs about their abilities in science are positively related to their performance in science.

Science self-efficacy explains 13.8% of the variance in science performance among students in Ireland and 5.8% among students on average across OECD countries (OECD, 2016b, Table I.3.4b). There is a score point difference of 89.9 between students scoring in the bottom and top quarters of Science Self-Efficacy in Ireland (Table 7.20). In addition, an increase of 27.3 score points in science is expected with a one standard deviation increase on the Science Self Efficacy scale in Ireland (Table 7.20). Across OECD countries on average, the difference in science scores between students with the highest and lowest science self-efficacy is 68.2 points. With a one unit increase on the Science Self Efficacy scale, a corresponding increase of 17.7 points on science is expected.

Table 7.20. Mean scores in science of students in the top and bottom quarters of the Science Self-Efficacy index, and association with overall science performance, in Ireland, and on average across OECD countries

	Science self-efficacy			
	Mean science score (SE)		Diff: Top-Bottom (SED)	Assoc w/index* (SE)
	Bottom Q index	Top Q index		
Ireland	459.4	548.3	**89.9**	**27.3**
	(3.22)	(3.16)	(3.61)	(0.99)
OECD	465.9	534.1	**68.2**	**17.7**
	(0.55)	(0.67)	(0.74)	(0.22)

Values in bold are statistically significant. SE = standard error of the mean; SED = standard error of the difference. * Indicates increase in science achievement corresponding with an increase of one standard deviation on the index.

7.4. Students' Beliefs about Science

In PISA 2015, a scientifically literate person is characterised as having an interest in science, as well as possessing important beliefs about science. These beliefs manifest in a disposition to value scientific approaches to enquiry, a concern for the environment and an environmentally sustainable way of life (OECD, 2016a, p.37). PISA assessed beliefs about science using items in the Student Questionnaire that were scaled into three indices: Epistemic Beliefs, Environmental Awareness and Environmental Optimism.

7.4.1. Epistemic beliefs

Epistemic Beliefs is a measure of students' attitudes towards science and scientific inquiry. Specifically, students' epistemic beliefs about science reflect the extent to which students value scientific approaches to enquiry and the insights generated from such enquiry (OECD, 2016a, p.37). The development of epistemic beliefs about science are considered an important aspect of science education as they impact on the generation of new knowledge. In PISA 2015, students are deemed to value scientific approaches to enquiry if their personal epistemic beliefs are consistent with current views about the nature of knowledge in science.

PISA asked students how much they disagree or agree with a set of statements reflecting epistemic beliefs. In Ireland, more than 9 out of ten students agreed or strongly agreed with the views that 'a good way to know if something is true is to do an experiment' (93.4%), 'ideas in science sometimes change' (91.8%), 'good answers are based on evidence from many different experiments' (93.2%), and 'it is good to try experiments more than once to make sure of your findings' (93.2%). More than 8 out of ten students agreed or strongly agreed that 'sometimes scientists change their minds about what is true in science' (81.6%), and that 'the ideas in science books sometimes change' (81.8%) (E-Appendix Table A7.27).

PISA constructed the index Epistemic Beliefs from students' responses to the six statements. Higher scores on the index reflect a higher belief in the value of scientific approaches to enquiry. Ireland's mean score on Epistemic Beliefs (0.21) is significantly higher than the mean score for OECD countries on average (-0.01) (Table 7.21). Countries scoring similarly to Ireland on Epistemic beliefs include New Zealand (0.22) and the United Kingdom (0.22). Highest scoring OECD countries include Portugal (0.28) and Iceland (0.29), and lowest scoring include Hungary (-0.36) and the Slovak Republic (-0.35) (OECD, 2016b, Table I.2.12a).

Table 7.21. Mean scores on the Epistemic Beliefs (valuing scientific approaches to enquiry) index, in Ireland and on average across OECD countries

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Epistemic beliefs	0.21	(0.01)	0.85	-0.01	(0.00)	0.99	**0.22**	(0.01)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

In Ireland, male and female students do not differ significantly in mean scores on Epistemic Beliefs (0.22 for males and 0.20 for females) (Table 7.22). Across OECD countries on average, there is a small, but significant, gender difference (-0.04) on Epistemic Beliefs in favour of females (OECD, 2016b (web-based), Table I.2.12c). Mean scores on Epistemic Beliefs are presented by school type, students' immigrant and language background, and school SPP (DEIS) status in Ireland in the E-Appendix Tables A7.28 to A7.30.

Table 7.22. Mean scores on the Epistemic Beliefs (valuing scientific approaches to enquiry) index, by gender, in Ireland and on average across OECD countries

	Epistemic beliefs					
	Males		Females		Difference	
	Mean	SE	Mean	SE	M-F	SED
Ireland	0.22	(0.02)	0.20	(0.02)	0.02	(0.03)
OECD	-0.02	(0.00)	0.01	(0.00)	**-0.04**	(0.00)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

Higher scores on the Epistemic Beliefs index are associated with higher performance on overall science among students in Ireland. The correlation between the two is in the moderate range is (r = .346, t = 24.72, p <.001) and is significant. In Ireland, differences among students in their epistemic beliefs about science account for 12.0% of the variance in science performance (OECD, 2016b, Table I.2.12b). The difference between students scoring in the bottom and top quarters of the index is 79.2 scale score points (Table 7.23). A 35.7 score point increase in science performance is associated with a one-standard-deviation increase on the Epistemic Beliefs index. Across OECD countries on average, there is a 91.4 point difference between students in the top and bottom quarters of the index, and a one unit increase on the index is associated with a 33.3 point increase in science.

Table 7.23. Mean scores in science of students in the top and bottom quarters of the Epistemic Beliefs index, and association with overall science performance, in Ireland and on average across OECD countries

	Epistemic beliefs			
	Mean science score (SE)		Diff: Top-Bottom (SED)	Assoc w/index* (SE)
	Bottom Q index	Top Q index		
Ireland	465.6	544.8	**79.2**	**35.7**
	(4.35)	(3.07)	(4.22)	(1.62)
OECD	452.9	544.3	**91.4**	**33.3**
	(0.63)	(0.61)	(0.78)	(0.28)

Values in bold are statistically significant. * Indicates increase in science achievement corresponding with an increase of one standard deviation on the index. SE = standard error of the mean; SED = standard error of the difference.

7.4.2. Environmental awareness and environmental optimism

In PISA 2015, environmental issues are considered an important aspect of students' beliefs that can impact on their performance in science (OECD, 2016a). PISA defines two types of beliefs about environmental issues: environmental awareness and environmental optimism. Environmental awareness and optimism are considered central aspects of science education, as both can affect students' engagement with environmental concerns (OECD, 2016a).

To assess environmental awareness, students were asked to indicate their familiarity with seven scientific issues (e.g., 'air pollution') by responding 'I have never heard of this', 'I have heard about this but I would not be able to explain what it is really about', 'I know something about this and could explain the general issue', or 'I am familiar with this and I would be able to explain this well'. Table 7.24 presents the percentages of students in Ireland responding 'I have never heard of this' or 'I am familiar with this and I would be able to explain it well to each item' (also see E-Appendix Table A7.31).

Almost half of students in Ireland indicated familiarity and confidence in explaining air pollution (47.5%), the consequences of clearing forests for other land use (46.6%), and the increase of greenhouse gases in the atmosphere (42.6%) (Table 7.24). Over one third of students in Ireland indicated familiarity and confidence in explaining extinction of plants and animals (39.7%) and shortage of water resources (34.1%). Overall, only a small percentage of students had never heard of the various science issues (1.6% for air pollution to 4.7% for the increase of greenhouse gases). However, one exception is the issue 'the use of genetically modified plants and animals (e.g. GMO crops)' for which almost one quarter of students (23.6%) responded with 'I have never heard of this', and just 9.7% indicated familiarity and confidence in their ability to explain the issue.

Table 7.24. Percentages of students responding 'I have never heard of this' and 'I am familiar with this and I would be able to explain it well' to various science issues, in Ireland

	I have never heard of this		I am familiar with this and I would be able to explain this well	
	%	SE	%	SE
The increase of greenhouse gases in the atmosphere	4.7	(0.41)	42.6	(1.01)
The use of genetically modified plants and animals (e.g. GMO crops)	23.6	(0.68)	9.7	(0.44)
Nuclear waste	4.1	(0.27)	17.3	(0.48)
The consequences of clearing forests for other land use	3.7	(0.35)	46.6	(0.80)
Air pollution	1.6	(0.19)	47.5	(0.79)
Extinction of plants and animals	2.9	(0.26)	39.7	(0.69)
Shortage of water resources	4.4	(0.32)	34.1	(0.78)

To assess students' environmental optimism, students were asked to indicate whether they think the seven environmental issues would improve, stay about the same, or get worse over the next 20 years. Despite indicating little familiarity with the issue of genetically modified plants and animals, students in Ireland were most optimistic about improvements in this area, with some 26.3% expecting improvements (E-Appendix Table A7.32). Overall, high percentages of students in Ireland think that the various environmental issues will get worse. Over 60% of students think that air pollution (63.2%), clearing of forests for other land use (62.5%), and the increase of greenhouse gases in the atmosphere (60.7%) will get worse. Over 40% of students think that extinction of plants and animals (55.7%), nuclear waste (45.2%), and shortage of water resources (42.3%) will get worse, and 31.6% of students think that the use of genetically modified plants and animals will get worse.

PISA constructed two indices, Environmental Awareness and Environmental Optimism, with higher scores representing greater levels of awareness or optimism. Ireland's mean scores on the Environmental Awareness (0.31) and Environmental Optimism (0.10) indices are significantly above the corresponding OECD averages (-0.07 and -0.03 respectively) (Table 7.25). The United Kingdom (0.30) scores similarly to Ireland on Environmental Awareness. Highest scoring OECD countries on the index include Portugal (0.68) and Turkey (0.58). Lowest scoring OECD countries include Japan (-0.48) and the Netherlands (-0.35). Countries scoring similarly to Ireland on Environmental Optimism include Hungary (0.10) and Spain (0.09). Highest scoring OECD countries on this index include Estonia (0.48), Japan (0.32) and Israel (0.30), and lowest scoring OECD countries include Turkey (-0.55) and Mexico (-0.36).

Table 7.25. Mean scores on the Environmental Awareness and Environmental Optimism indices, in Ireland and on average across OECD countries

	Ireland			OECD			Difference	
	Mean	SE	SD	Mean	SE	SD	IRL-OECD	SED
Environmental awareness	0.31	(0.02)	1.13	0.07	(0.00)	1.15	**0.24**	(0.02)
Environmental optimism	0.10	(0.02)	1.09	-0.03	(0.00)	1.15	**0.13**	(0.02)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

There are clear gender differences among students in Ireland in relation to both Environmental Awareness and Environmental Optimism (Table 7.26). Male students have significantly higher mean scores than female students on both indices (0.39 for males versus 0.24 for females on Environmental Awareness, and 0.18 for males versus 0.01 for females on Environmental Optimism), indicating a greater familiarity with the various science issues, and greater optimism about improvements in these areas. Gender differences on both indices are also observed for OECD countries on average. However, while male students score significantly higher on Environmental Optimism (by 0.17 points), females score significantly higher on Environmental Awareness (by 0.01 points).

Table 7.26. Mean scores on the Environmental Awareness and Environmental Optimism indices, by gender, in Ireland, and on average across OECD countries

	Ireland			OECD		
	Males	Females	Diff	Males	Females	Diff
	Mean (SE)	Mean (SE)	M-F (SED)	Mean (SE)	Mean (SE)	M-F (SED)
Environmental awareness	0.39	0.24	**0.15**	0.08	0.09	**-0.01**
	(0.02)	(0.03)	(0.04)	(0.00)	(0.00)	(0.00)
Environmental optimism	0.18	0.01	**0.17**	0.17	0.00	**0.17**
	(0.02)	(0.02)	(0.03)	(0.00)	(0.00)	(0.00)

Significant differences are in bold. SE = standard error of the mean; SED = standard error of the difference.

In Ireland, students in girls' secondary schools have significantly lower mean scores on Environmental Awareness than do students in boys secondary schools (0.31 for girls' versus 0.45 for boys'), but their mean score does not differ from the mean scores of students in mixed, vocational, or community/comprehensive schools (E-Appendix Table A7.33). Students in girls' secondary schools have a significantly lower mean score (-0.03) on Environmental Optimism than do students in boys' (0.11), mixed (0.12), vocational (0.14), and community/comprehensive (0.15) secondary schools.

In Ireland, native students score significantly lower (0.29) than immigrant students who speak English or Irish at home (0.47) on Environmental Awareness, but do not differ significantly from them on Environmental Optimism (E-Appendix Table A7.34). No differences exist between native students and immigrant students who speak other languages at home on the environmental indices.

Students in schools in the SSP score significantly lower (0.09) than students in non-SSP schools (0.36) on the Environmental Awareness scale, but do not differ significantly from them on Environmental Optimism (E-Appendix Table A7.35).

Environmental Awareness is related to performance in science among students in Ireland, with a significant correlation in the moderate range (.29) (Table 7.27). A weak-to-moderate negative correlation (-.12) exists between environmental optimism and performance in overall science indicating that less optimistic students are likely to score higher on science and vice versa.

Table 7.27. Correlations of Environmental Awareness and Environmental Optimism with performance in science, in Ireland

	Science		
	r	*t*	*p*
Environmental awareness	**.293**	2.09	<.05
Environmental optimism	**-.124**	-7.29	<.001

Significant correlations are in bold. Df=80 (number of variance strata associated with balanced repeated replication (BRR) method of variance estimation).

7.5. Summary and Conclusion

This chapter firstly addressed students' engagement with science as assessed by their expectations of a science career at age 30, their participation in science-related activities, and their intentions to study science for the Leaving Certificate. Around eight out of ten students in Ireland, and more female students than male students, is studying or intending to study a science subject to Leaving Certificate level. However, less than one-third of students in Ireland expects to be in a science-related career at age 30. The majority of those who expect a science career envisage a health-care profession such as nursing or physiotherapy. Females account for the majority of those choosing a career in health professions, while males are more likely to choose a science career in the engineering field. Overall, there appears to be little participation in science-related activities inside or outside of school among students in Ireland, or indeed among students across OECD countries on average. However, participation in science-related activities is significantly associated with achievement in science. When students in Ireland engage with science activities, it tends to be via the Internet more so than through books, magazines or groups, and participation is significantly higher among male students than female students.

Secondly, this chapter described students' motivation for learning science, focusing on their intrinsic motivation, or how interesting and fun they find learning science (Enjoyment of Science), on how useful they perceive studying science to be for their future plans (Instrumental Motivation), and on their interest in science topics (Interest in Science Topics). The majority of students in Ireland like learning about science, but fewer have fun doing so, and fewer still like reading about science. Students in Ireland report greater enjoyment of science than do students on average across OECD countries and greater interest in science topics. Of most interest to students in Ireland is how science can help prevent disease, followed by the Universe and its history. Male students in Ireland are more interested in physics- and chemistry-type topics (motion and forces, energy and its transformation) than females, while females are more interested in disease prevention. Students are least interested in the biosphere, and around 13% do not know what it is.

In Ireland, male students have more intrinsic motivation for science learning than female students, but they do not differ from female students in how useful they perceive science to be for their future study and career plans. Students in girls' secondary schools, however, display significantly greater instrumental motivation for science learning than students in boys' secondary schools. The majority of students in Ireland recognise the instrumental value in studying science, with some 78.1% agreeing or strongly agreeing that 'making an effort in my science subject(s) is worth it because this will help me in the work I want to do later on'. Overall, students in Ireland have greater instrumental motivation for science learning than do students on average across OECD countries. Instrumental motivation has a weak-to-moderate positive relationship with performance in science. Moderate positive associations exist between intrinsic motivation (both Enjoyment of Science and Interest in Science Topics) and science performance.

Thirdly, this chapter described students' self-beliefs about science. In Ireland, performance in PISA science is significantly associated with science self-efficacy, or students' beliefs in their ability to use scientific knowledge to complete real world science tasks. Students in Ireland are most confident in their ability to 'explain why earth quakes occur more frequently in some areas than others', and least confident in their ability to 'discuss how new evidence can lead you to change your understanding about the possibility of life on Mars'. Ireland's score on Science Self-efficacy does not differ significantly from the OECD average. In Ireland, and across OECD countries on average, male students score significantly higher on Science Self-efficacy than female students. Also, in Ireland, students' beliefs about their abilities in science are positively related to their performance in science.

Finally, this chapter addressed students' beliefs about science. Specifically, the chapter described students' epistemic beliefs, or the extent to which students value scientific approaches to enquiry, their environmental awareness, and their optimism with regard to improvements in various environmental issues. Students in Ireland have a high degree of support for scientific approaches to enquiry, as indicated by the very high levels of agreement with various statements reflecting their epistemic beliefs. For example, more than 90% of students were in agreement that 'a good way to know if something is true is to do an experiment' and 'good answers are based on evidence from many different experiments'. Students in Ireland score well above the OECD average on Epistemic Beliefs and have one of the higher mean scores on the scale among all participating countries/ economies. In Ireland, male students and female students do not differ significantly in their epistemic beliefs. Across OECD countries on average, there is a slight, but significant, gender difference in epistemic beliefs in favour of females.

PISA asked students about their familiarity with a range of environmental issues such as air pollution and nuclear waste. Overall, students in Ireland have a high degree of familiarity with the majority of the issues. For example, almost half of students report being familiar with and able to explain 'air pollution' and 'the consequences of clearing forests for other land use'. However, almost one quarter of students in Ireland have never heard of 'the use of genetically modified plants and animals' (e.g., GMO crops). PISA also assessed students' environmental optimism by asking students whether they think each environmental issue will improve, stay about the same, or get worse. High percentages of students in Ireland think that the various issues will get worse. Indeed, over 60% of students think that 'air pollution', 'clearing of forests for other land use', and the 'increase in greenhouse gases' will get worse. Students in Ireland were most optimistic about 'the use of genetically modified plants and animals', with around one quarter expecting improvements.

Ireland scores above the OECD averages on both Environmental Awareness and Environmental Optimism. In Ireland, there is a clear gender difference in favour of male students on both indices. Also, students in girls' secondary schools score significantly lower on both Environmental Awareness and Environmental Optimism relative to students in boys' secondary schools. Environmental Awareness is positively related to science performance among students in Ireland. A weak-to-moderate negative correlation exists between Environmental Optimism and performance in overall science.

Chapter 8: Trends in Performance and School and Student Variables

This chapter looks at changes in performance on science, reading literacy and mathematics, compared with earlier PISA cycles. It also looks at demographic trends at school and student levels and changes in students' attitudes towards science and their career aspirations. It also looks at performance on clusters of test items across PISA cycles, and how new approaches to scaling PISA data could have affected mean scores in earlier cycles if those approaches had been in place earlier.

As noted in Chapter 1, the PISA 2006, 2009, 2012 and 2015 assessments use the same science performance scale, and score points on the scale are intended to be comparable over time. In the same way, performance on reading literacy can be mapped back to the 2000 scale, and performance in mathematics can be mapped back to 2003. The OECD (2016b) argues that trends in performance on a domain should be mapped back to the year(s) in which it was a major domain. Hence, it is preferable to compare 2015 with 2006 for science, 2015 with 2009 (and 2000) for reading, and 2015 with 2012 (and 2003) for mathematics. Other comparisons, such as those between 2012 and 2015 science, should be treated with greater caution as these are underpinned by a minor to major link.

As described in Chapter 1, a number of changes to the PISA assessment design, the calibration sample (the subsample of students on which trends are based), the assessment mode (computer-based rather than paper-based), the scaling process (the use of a 'hybrid' one- and two-parameter IRT model for the first time), the treatment of differential item functioning across countries, and the treatment of non-reached items all changed since previous cycles. Hence, any observed changes in performance over time may arise for a number of reasons, rather than one single reason such as the transition to computer-based assessment.

The analysis of demographic information in the current chapter is designed to identify any changes in the PISA samples for Ireland in 2012 and 2015. In this context, reference is also made to adjusted scores provided by the OECD (2016b). These adjusted scores are estimates of performance in earlier cycles, reweighted to mirror the characteristics of the PISA 2015 sample.

The attitudes towards science examined in this chapter include enjoyment of science, instrumental motivation to learn science, and science self-efficacy. Engagement in science-related activities and students' career aspirations at age 30 are also considered.

Additional tables based on this chapter are in the PISA 2015 E-Appendix*,* available at www.erc.ie/pisa.

8.1. Trends in Science Performance

Science was the major assessment domain in two PISA cycles, 2006 and 2015. This means that detailed information is available on performance in those years, including performance by subscale.

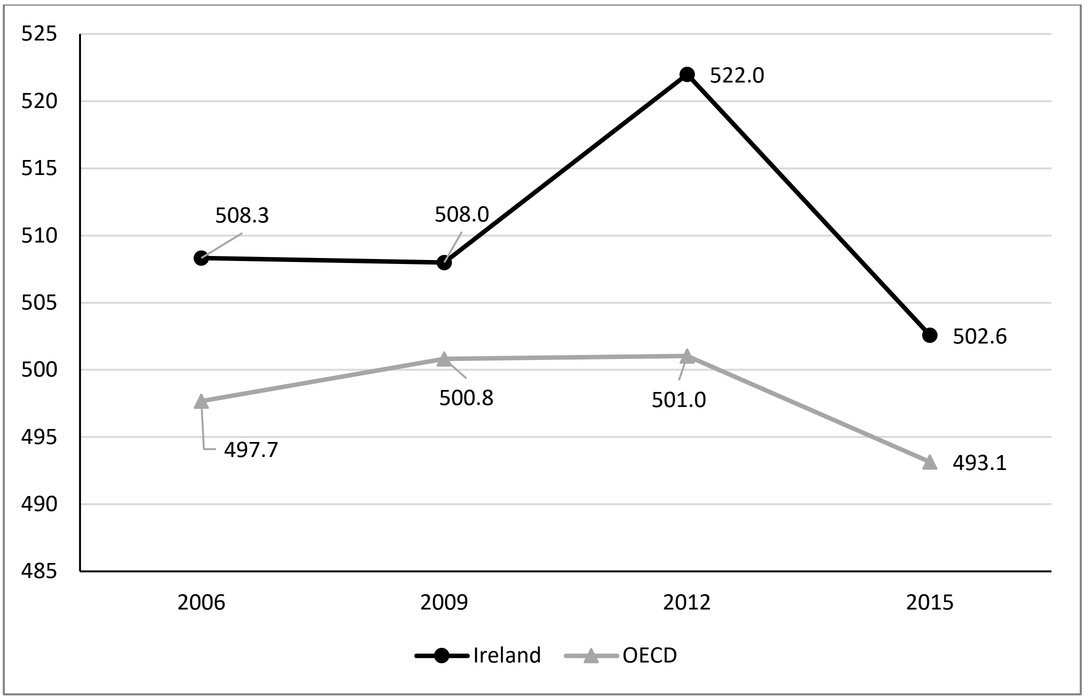
This section is divided into five parts. First, trends in mean overall science scores are considered. Second, trends in overall science proficiency levels are considered. Third, trends in performance at key percentile scores and trends in variation in science performance across cycles are described. Fourth, trends on overall science performance by gender are examined. The section concludes with a note on trends across science subscales between 2006 and 2015.

8.1.1. Trends in overall science mean scores

Ireland's mean score on overall science in PISA 2006 was 508.3 (Figure 8.1). This dropped marginally to 508.0 in 2009, but increased significantly to 522.0 by 2012, before falling back to 502.6 in 2015. On average across OECD countries, performance increased between 2006 (497.7) and 2012 (501.0), but fell back to 493.1 in 2015. In all PISA cycles to date, including 2015, Ireland's mean score on science has been significantly higher than the OECD average score (see E-Appendix Table A8.1).

As noted in Chapter 2, an improvement in science in Ireland in 2009 may have been masked. In that year, students in Ireland performed considerably less well on reading literacy and mathematics than in earlier cycles, but performed at about the same level on science. This suggests that performance on science may well have been potentially higher in 2009, but was pulled back by some of the factors that may have affected performance on reading literacy and mathematics, such as demographic changes, issues with scaling methodology (and in particular, the method used to estimate link error), and low levels of engagement among students (Cosgrove, 2015).

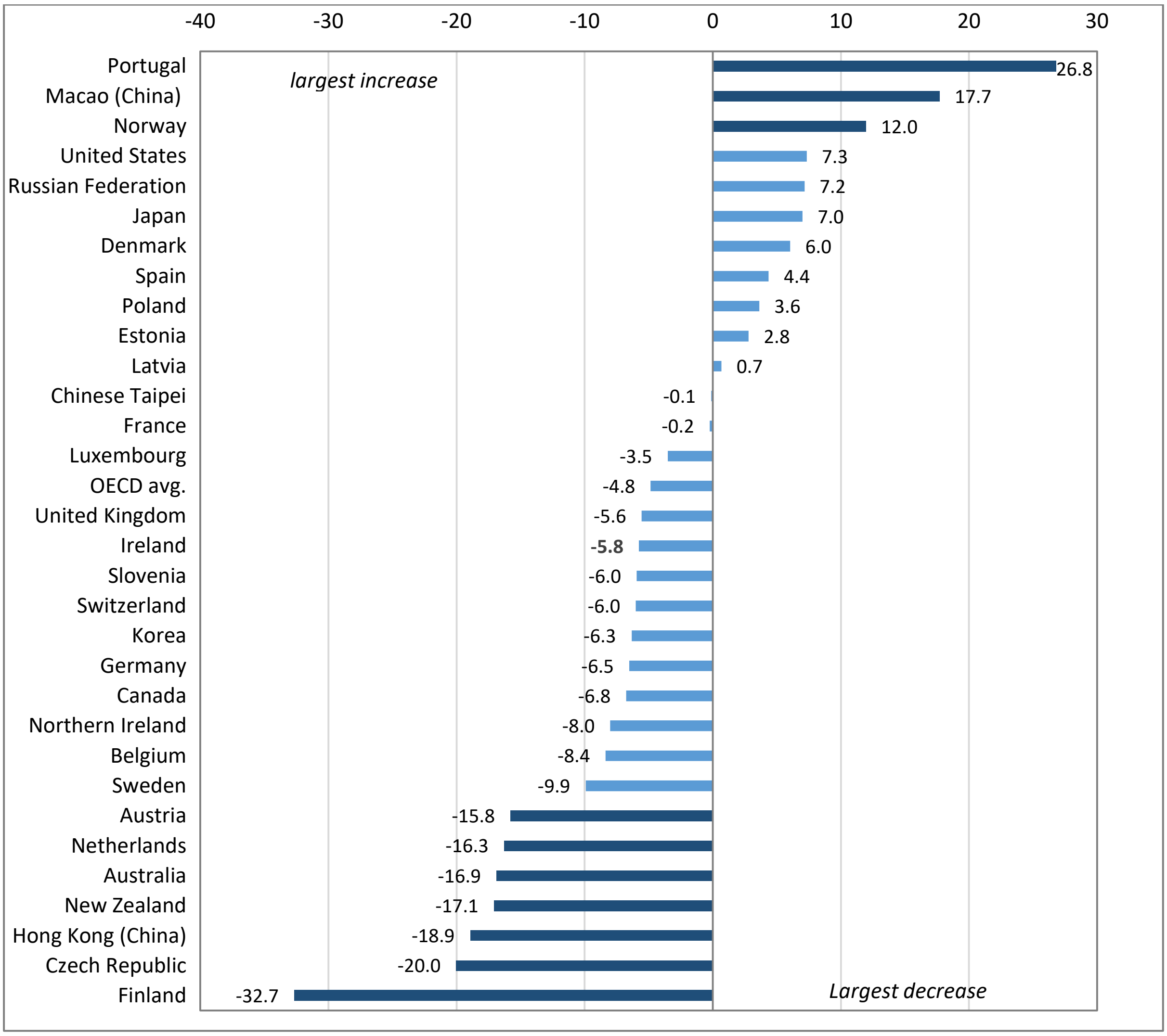
Figure 8.1. Mean scores on the overall science scale in Ireland and the average across OECD countries, 2006-2015



Among a group of 30 high-performing countries in PISA 2012, three experienced a significant increase in performance on overall science between 2006 (when science was also a major domain in PISA) and 2015: Portugal (+26.8 points), Macao (China) (+17.7) and Norway (+12.0) (Figure 8.1). Seven countries experienced significant declines in performance, including Finland (-32.7), the Czech Republic (-20.0), Hong Kong (China) (-18.9), New Zealand (-17.1), Australia (-16.9), the Netherlands (-16.3), and Austria (-15.8). A number of countries, including Ireland (-5.8) and Northern Ireland (-8.0), experienced non-significant changes in performance between 2006 and 2015.

In addition to reporting on mean scores across PISA cycles, the OECD uses linear regression to produce average 3-year trends in science. Three-year average trends smooth out the fluctuations in performance from cycle to cycle (such as Ireland's unusually high score in 2012). Ireland's average three-year trend, covering the period 2006 to 2015, is -0.4 score points, indicating a non-significant decline of less than one score point across PISA cycles (OECD, 2016b, Table I.2.4a). The corresponding OECD average 3-year trend is a non-significant -1.3. Hence, across the period 2006 to 2015, performance in Ireland and on average across OECD countries was relatively stable.

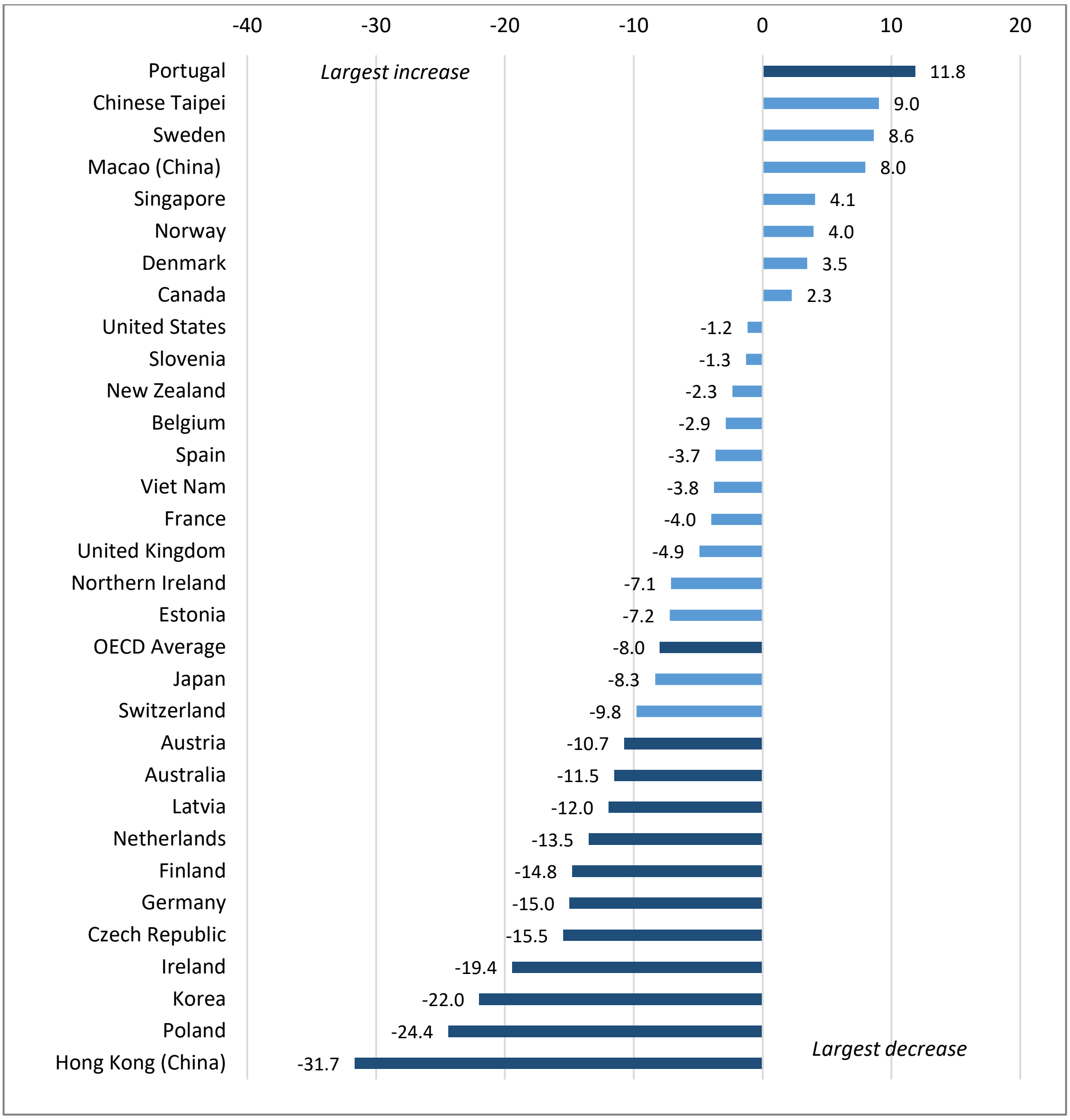
Figure 8.2. Mean score differences in science between 2006 and 2015 for the top 30 performing countries/economies in 2015 that participated in PISA 2006 and PISA 2015, the OECD average difference, and the difference in Northern Ireland



Significant differences are in bold. OECD avg. refers to all OECD countries.

Figure 8.3 looks at the differences in overall science between 2012 and 2015, for the 30 highest-performing countries in PISA 2015 science, the average difference across OECD countries, and the difference in Northern Ireland. Just one country – Portugal – has a significant increase in performance between 2012 and 2015. On the other hand, there are significant declines in performance in 11 countries and on average across OECD countries. The largest differences are observed in Hong Kong (China) (-31.7), Poland (-24.4), Korea (-22.0), and Ireland (-19.4). Performance dropped by 7.1 score points in Northern Ireland, but this is not statistically significant.

Figure 8.3. Mean score differences in science between 2012 and 2015 for the top 30 performing countries/economies in 2015 that participated in PISA 2012 and PISA 2015, the OECD average difference, and the difference in Northern Ireland



Significant differences are in bold. OECD avg. refers to all OECD countries.

Table 8.1 provides an analysis of the mean science scores for Ireland, four countries that performed at about the same level as Ireland on PISA 2012 science, Korea (which experienced a large decline between 2012 and 2015), and the average difference across OECD countries. Australia, the Netherlands, Germany and Canada had mean scores that were not significantly different from Ireland's in 2012. However, like Ireland, four of the five (Australia, the Netherlands, Germany and Korea) saw significant drops in performance by 2015, while there was a small, non-significant increase in Canada. Along with Canada, Korea and Australia had mean scores that were significantly higher than Ireland's in 2015 (see Chapter 4, Table 4.1). For Australia, this occurs because its decline in performance was smaller than in Ireland, while Canada had a small increase. Korea started from a much higher base than Ireland in 2012. Average three-year trend scores in science (between 2006 and 2015) show significant declines in Australia, the Netherlands, and, as noted earlier, small and non-significant changes in Ireland and on average across OECD countries.

Table 8.1. Comparison of mean science scores for Ireland, selected countries, and on average across OECD countries, 2006-2015

	Ireland		OECD		Australia		Korea		Netherlands		Germany		Canada	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
2006	508.3	(3.19)	497.7	(0.50)	526.9	(2.26)	522.1	(3.36)	524.9	(2.74)	515.6	(3.80)	534.5	(2.03)
2009	508.0	(3.27)	500.8	(0.49)	527.3	(2.53)	538.0	(3.44)	522.2	(5.42)	520.4	(2.80)	528.7	(1.62)
2012	522.0	(2.45)	501.0	(0.49)	521.5	(1.76)	537.8	(3.66)	522.1	(3.51)	524.1	(2.96)	525.4	(1.93)
2015	502.6	(2.39)	493.1	(0.44)	510.0	(1.54)	515.8	(3.13)	508.6	(2.26)	509.1	(2.70)	527.7	(2.08)
	Diff	SED	Diff	SED	Diff	SED	Diff	SED			Diff	SED	Diff	SED
2015-2006	-5.8	(5.99)	-4.5	(4.53)	**-16.9**	(5.25)	-6.3	(6.42)	**-16.3**	(5.72)	-6.5	(6.46)	-6.8	(5.34)
2015-2009	-5.4	(6.05)	-7.7	(4.55)	**-17.3**	(5.39)	**-22.2**	(6.47)	-13.6	(7.40)	-11.3	(5.95)	-1.0	(5.22)
2015-2012	**-19.4**	(5.20)	**-7.9**	(3.98)	**-11.5**	(4.56)	**-22.0**	(6.21)	**-13.5**	(5.73)	**-15.0**	(5.61)	2.3	(4.84)
Average 3-year trend in science across PISA assessments														
	-0.4	(1.99)	-1.3	(1.51)	**-5.7**	(1.73)	-1.9	(2.10)	**-4.9**	(1.94)	-1.7	(2.08)	-2.3	(1.75)

Significant differences are in bold. OECD average excludes Austria.

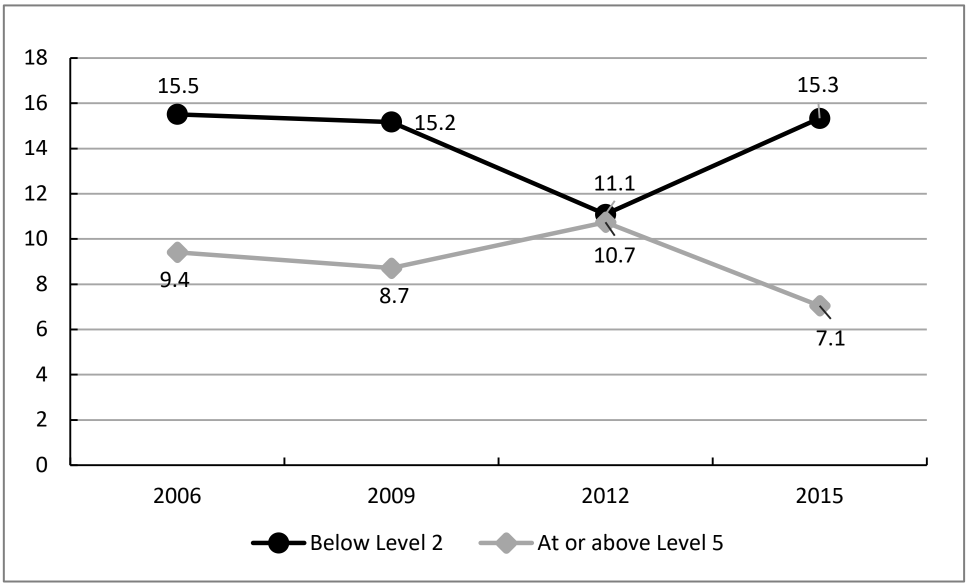
8.1.2. Trends in performance on science proficiency levels

As noted in Chapter 4, performance on PISA science can also be described in terms of proficiency levels, with the lowest performers defined as those achieving below Level 2, and the highest as those achieving at or above Level 5. Figure 8.4 shows the percentages of students in Ireland achieving below Level 2 and at or above Level 5 on overall science in each cycle from 2006 to 2015. The percentages achieving below Level 2 are virtually identical in 2006, 2009 and 2015. In line with Ireland's higher mean score in 2012, just 11.1% of students performed below Level 2 in that year, with a significant increase of 4.2% between 2012 and 2015 (E-Appendix Table A8.2).

A somewhat similar pattern is apparent when the proficiency of high performers is considered. In Ireland, 9.4% of students performed at Level 5 or above in 2006, and this increased to 10.7% in 2012, before dropping to 7.1% in 2015. The 2.4% decline between 2006 and 2015 and the 3.7% decline between 2012 and 2015 are both statistically significant (E-Appendix Table A8.3).

It is noteworthy that there was a significant decline in the percentage of students performing at or above Level 5 between 2006 and 2015, when the difference between mean scores was relatively small (-5.8 points), and the percentages performing below Level 2 were almost identical.

Figure 8.4. Percentage of students below Proficiency Level 2 and at or above Proficiency Level 5 on the science scale in Ireland, 2006-2012



8.1.3. Trends in performance at key percentile markers and variation in science performance

Students performing at the 10th percentile can be considered low performers, while those scoring at the 90th percentile can be considered high performers. In Ireland, the scores of students performing at the 10th percentile were broadly similar in 2006 (385.3), 2009 (382.3) and 2015 (386.7) (Table 8.2). In 2012, in line with Ireland's higher mean score, the score of students at the 10th percentile was also higher, at 403.9. These outcomes are broadly consistent with the proportions performing below Level 2 on the science proficiency scale. On average across OECD countries, performance at the 10th percentile is significantly lower, by 12.5 points, in 2015, compared with 2012. The corresponding drop in Ireland, 17.1 score points, is also significant.

Students in Ireland performing at the 90th percentile achieved a score of 630.3 in 2006, 627.3 in 2009, 636.6 in 2012, and 617.6 in 2015 (Table 8.2). The significant drop of 19.0 score points between 2012 and 2015 is consistent with the decline in Ireland's mean score by 19.4 score points between these years. On average across OECD countries, the decline in performance at the 90th percentile between 2012 and 2015 (-3.5 score points) is not statistically significant.

Table 8.2 also shows that the scores of students in Ireland at the 10th percentile were well above the corresponding OECD average scores at that marker in all years between 2006 and 2015. However, scores at the 90th percentile were closer to the corresponding OECD average scores except in 2012. In 2015, when the score of students in Ireland at the 90th percentile was 617.6, and the OECD average was 614.6. The difference of three score points is not statistically significant.

Table 8.2. Comparisons of scores of students performing at the 10th percentile and 90th percentile on the science scale in Ireland and on average across OECD countries, 2006-2015

	Ireland				OECD			
	10th Percentile		90th Percentile		10th Percentile		90th Percentile	
	Score	SE	Score	SE	Score	SE	Score	SE
2006	385.3	(4.41)	630.3	(3.75)	373.4	(0.78)	619.4	(0.66)
2009	382.3	(4.89)	627.3	(4.00)	378.3	(0.81)	618.6	(0.62)
2012	403.9	(4.79)	636.6	(2.58)	380.3	(0.77)	618.2	(0.64)
2015	386.7	(3.91)	617.6	(2.53)	367.8	(0.64)	614.6	(0.56)
	Diff	SED	Diff	SED	Diff	SED	Diff	SED
2015-2006	1.4	(7.41)	**-12.7**	(6.37)	-5.5	(4.59)	-4.7	(4.56)
2015-2012	**-17.1**	(7.32)	**-19.0**	(5.33)	**-12.5**	(4.05)	-3.5	(4.01)
Average 3-year trend in percentiles across PISA assessments								
	2.5	(2.38)	-2.9	(2.15)	-1.4	(1.53)	-1.4	(1.52)

Significant differences in bold. OECD average excludes Austria. SE = standard error; SED = standard error of the difference.

Table 8.3 shows that the standard deviation (a measure of the spread of scores) in Ireland dropped from 94.4 points in 2006 to 88.9 in 2015. The difference, 5.5 score points, is statistically significant and points to a narrowing of performance, compared with earlier cycles. This is also evident in the inter-decile range or the gap in performance between students scoring at the 90th and 10th percentiles, which has narrowed considerably since 2006 and is now 230.9 points. On average across OECD countries, the standard deviation was broadly similar between 2006 and 2015 (ranging between 92.4 and 94.9), and, while the inter-decile range dropped from 246.0 in 2006 to 240.3 in 2009, it was back up to 246.8 in 2015.

Table 8.3. Variation in science performance in Ireland and on average across OECD countries, 2006-2015

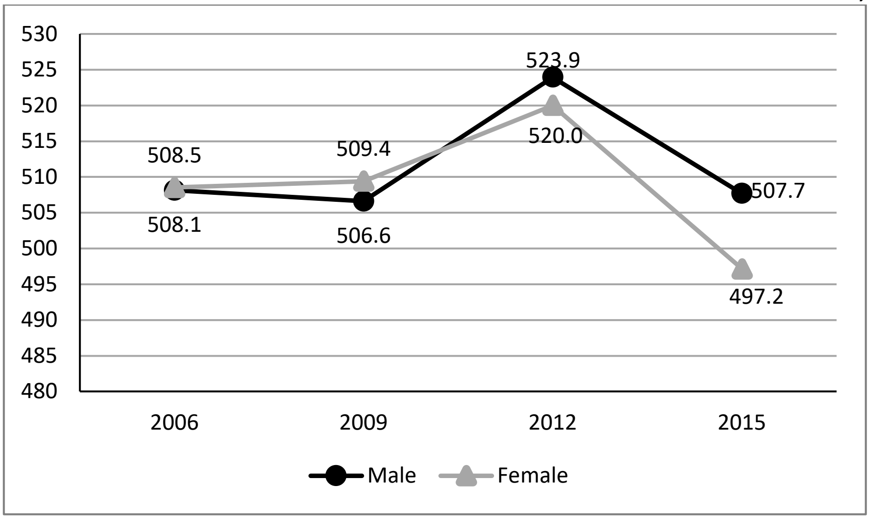
	Ireland				OECD			
	Standard deviation		Inter-decile range (90th minus 10th percentile)		Standard deviation		Inter-decile range (90th minus 10th percentile)	
	SD	SE	Score diff.	SED	SD	SE	Score diff.	SED
2006	94.4	(1.50)	245.0	(4.89)	94.9	(0.29)	246.0	(0.91)
2009	97.1	(2.10)	245.1	(5.55)	93.3	(0.31)	240.3	(0.92)
2012	91.3	(1.58)	232.7	(4.91)	92.4	(0.28)	237.9	(0.87)
2015	88.9	(1.33)	230.9	(4.10)	94.3	(0.23)	246.8	(0.75)
2015-2006	**-5.5**	(2.01)	**-14.1**	(6.38)	-0.6	(0.37)	0.8	(1.17)
2015-2012	-2.4	(2.07)	-1.8	(6.39)	**1.9**	(0.36)	**8.9**	(1.14)

Significant differences are in bold. OECD average excludes Austria. SE = standard error; SED = standard error of the difference.

8.1.4. Trends in science performance by gender

From 2006 to 2012, male students in Ireland had marginally higher mean scores than females, but differences were not statistically significant (Figure 8.5, E-Appendix Table A8.4). In 2015, the difference in favour of male students (10.5 score points) was statistically significant. Furthermore, while the mean score of male student dropped by 16.2 points between 2012 and 2015, the mean score of female students dropped by 22.8 points.

Figure 8.5. Mean scores of male and female students on the overall science scale in Ireland, 2006 to 2015



On average across OECD countries, male students had a mean score in 2006 that significantly exceeded that of females, by 2.1 score points. By 2015, the gap had widened to a significant 3.5 points (Table 8.4). Among a set of comparison countries (those that performed at a level similar to Ireland on PISA 2012 science and Korea), Germany also posted a significant gender difference (10.5 points in favour of male students) in 2015. In Korea, there was a non-significant difference of 9.6 score points in favour of female students (the standard errors for Korean students' mean scores were particularly large, relative to those of other countries).

Table 8.4. Comparisons of science scores of male and female students in Ireland, in selected countries and on average across OECD countries, 2006-2015

	2006						2015					
	Male		Female				Male		Female			
	Mean	SE	Mean	SE	Diff	SED	Mean	SE	Mean	SE	Diff	SED
Ireland	508.1	(4.33)	508.5	(3.31)	-0.4	(4.31)	507.7	(3.16)	497.2	(2.62)	**10.5**	(3.21)
OECD	499.1	(0.63)	497.0	(0.57)	**2.1**	(0.68)	495.0	(0.54)	491.4	(0.49)	**3.5**	(0.58)
Australia	526.9	(3.19)	526.9	(2.65)	0.0	(3.76)	511.0	(2.12)	508.9	(1.72)	2.1	(2.34)
Korea	521.2	(4.80)	523.1	(3.85)	-1.9	(5.55)	511.2	(4.59)	520.8	(3.27)	-9.6	(5.01)
Netherlands	528.4	(3.21)	521.2	(3.05)	**7.2**	(3.03)	510.6	(2.91)	506.5	(2.46)	4.1	(2.95)
Germany	519.1	(4.58)	512.0	(3.80)	7.1	(3.71)	514.3	(3.22)	503.8	(2.77)	**10.5**	(2.59)
Canada	536.5	(2.49)	532.4	(2.12)	4.1	(2.19)	528.3	(2.52)	527.2	(2.25)	1.1	(2.36)

Significant differences are in bold. OECD average excludes Austria. SE = standard error; SED = standard error of the difference.

Gender differences in science can also be examined with reference to proficiency levels (Table 8.5). In Ireland, 16.5% of male students performed below Level 2 in 2006, and this fell to 15.7% by 2015 (a non-significant drop of 0.9 points). Similarly, the proportion of female students performing below Level 2 was about the same in 2006 and 2015 (14.5% and 14.9% respectively). On the other hand, while marginally fewer male students performed at or above Level 5 in 2015 (9.0%) compared with

2006 (10.3%), significantly fewer female students performed at that level in 2015 (5%) compared with 2006 (8.5%). Compared with 2012, marginally more males (4.1%), and significantly more females (4.7%) performed below Level 2 in 2015, while significantly fewer males (-2.7%) and females (-4.7) performed at or above Level 5. These data indicate that female students fared less well than male students in 2015 compared with earlier cycles, especially at Level 5 and above.

Table 8.5. Percentage of male and female students below Proficiency Level 2 and at or above Proficiency Level 5 on the science scale in Ireland, 2006 and 2015

	Below Level 2				At or above Level 5			
	Male		Female		Male		Female	
	%	SE	%	SE	%	SE	%	SE
2006	16.5	(1.54)	14.5	(1.09)	10.3	(1.00)	8.5	(0.80)
2012	11.6	(1.25)	10.6	(1.09)	11.7	(0.80)	9.7	(0.85)
2015	15.7	(1.22)	14.9	(1.12)	9.0	(0.76)	5.0	(0.51)
	Diff	SED	Diff	SED	Diff	SED	Diff	SED
2015-2006	-0.9	(2.77)	0.4	(2.08)	-1.3	(1.43)	**-3.5**	(1.00)
2015-2012	4.1	(2.30)	**4.4**	(1.87)	**-2.7**	(1.21)	**-4.7**	(1.02)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

On average across OECD countries, the percentages of male and female students performing below Level 2 were marginally higher in 2015 than in 2006, by 1.5% and 1.4% respectively (E-Appendix Table A8.5). The percentage of males performing at or above Level 5 was marginally lower in 2015, by 0.8%, while the percentage of females performing at or above Level 5 was significantly lower, by 1.3%. It is noteworthy that, in 2015, there are significantly fewer female students performing at or above Level 5 in Ireland (5.0%) than on average across OECD countries (6.5%), while the percentages of male students is about the same (9.7% and 8.9% respectively).

8.1.5. Trends in performance on science subscales

Since PISA science was a major domain in both 2006 and 2015, science subscale scores were computed for both years. However, the subscales are not directly comparable across cycles due to changes in how they are labelled, and the criteria used to assemble them. For example, in 2006, Knowledge of Science items were further divided into knowledge systems subscales (Physical, Living, and Earth and Space), and Knowledge about Science items were not categorised in this way. In 2015, all science items were categorised into one of the three science knowledge systems. The OECD did not issue trend comparisons on science subscales for PISA 2015. However, we can discern the following about gender differences on the science scales in Ireland in 2006 and 2015:

- Male students in Ireland outperformed females on Explain Phenomena Scientifically in both 2006 and 2015
- Females outperformed males on Knowledge about Science in 2006, while there was no significant difference between males and females on the broadly-equivalent Procedural and Epistemic Knowledge subscale in 2015
- Males outperformed females on two of three systems subscales in 2006 (Earth and Space, Physical Systems) with no difference on Living Systems. In 2015, males outperformed females on all three.

8.2. Trends in Reading Literacy Performance

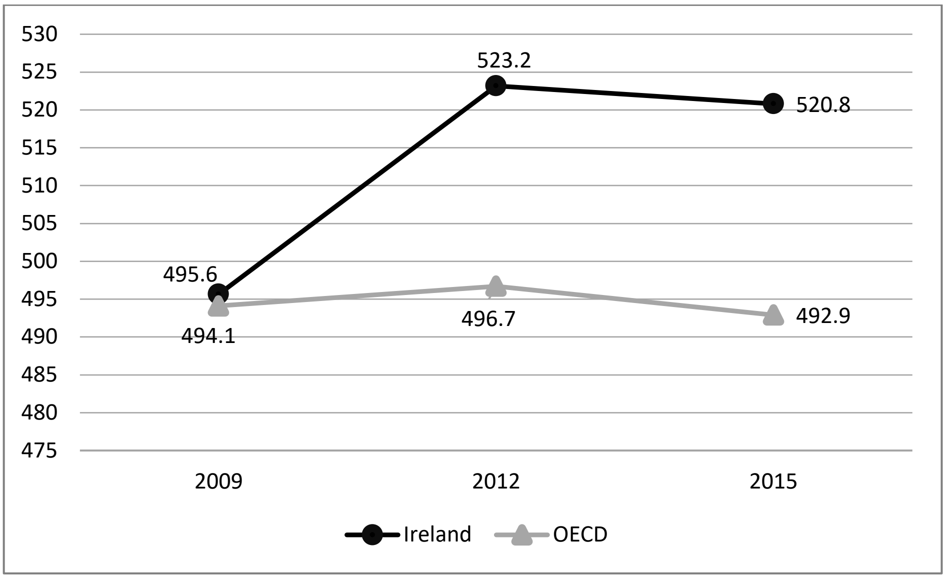
Reading literacy was a major assessment domain in 2009, and a minor domain in 2012 and 2015. Hence, detailed information on performance in 2015 is not available. However, there was a greater number of link items (items linking back to the 2009 assessment) in 2015 (88 items) compared with 2012 (44). The purpose of doubling the number of link items was to achieve greater construct coverage and reduce uncertainty in linking scales from cycle to cycle (OECD, 2016b).

This section is divided into four parts. First, trends in mean overall reading literacy scores are considered. Second, trends in overall reading proficiency levels are considered. Third, trends on percentile scores and variation in reading literacy performance across cycles are described. Fourth, trends on reading literacy performance by gender are examined.

8.2.1. Trends on overall reading literacy mean scores

As noted in Chapter 2, there was a significant decline in reading literacy in Ireland in 2009, compared with earlier cycles, including 2000. As shown in Figure 8.6, performance improved between 2009 and 2012, by 27.6 score points, and was relatively stable between 2012 and 2015, with a non-significant drop of 2.4 score points (see E-Appendix Table A8.6). On average across OECD countries, there was a small decline between 2009 and 2015 (-1.2) and also a non-significant decline (-3.7) between 2012 and 2015. In 2009, the difference between Ireland's mean score and the average score across OECD countries was not statistically significant (1.5 points in favour of Ireland). Students in Ireland achieved significantly higher mean scores than on average across OECD countries in 2012 (+26.5) and in 2015 (+27.9) (E-Appendix Table A8.6).

Figure 8.6. Mean scores on overall reading literacy in Ireland and on average across OECD countries, 2009-2015

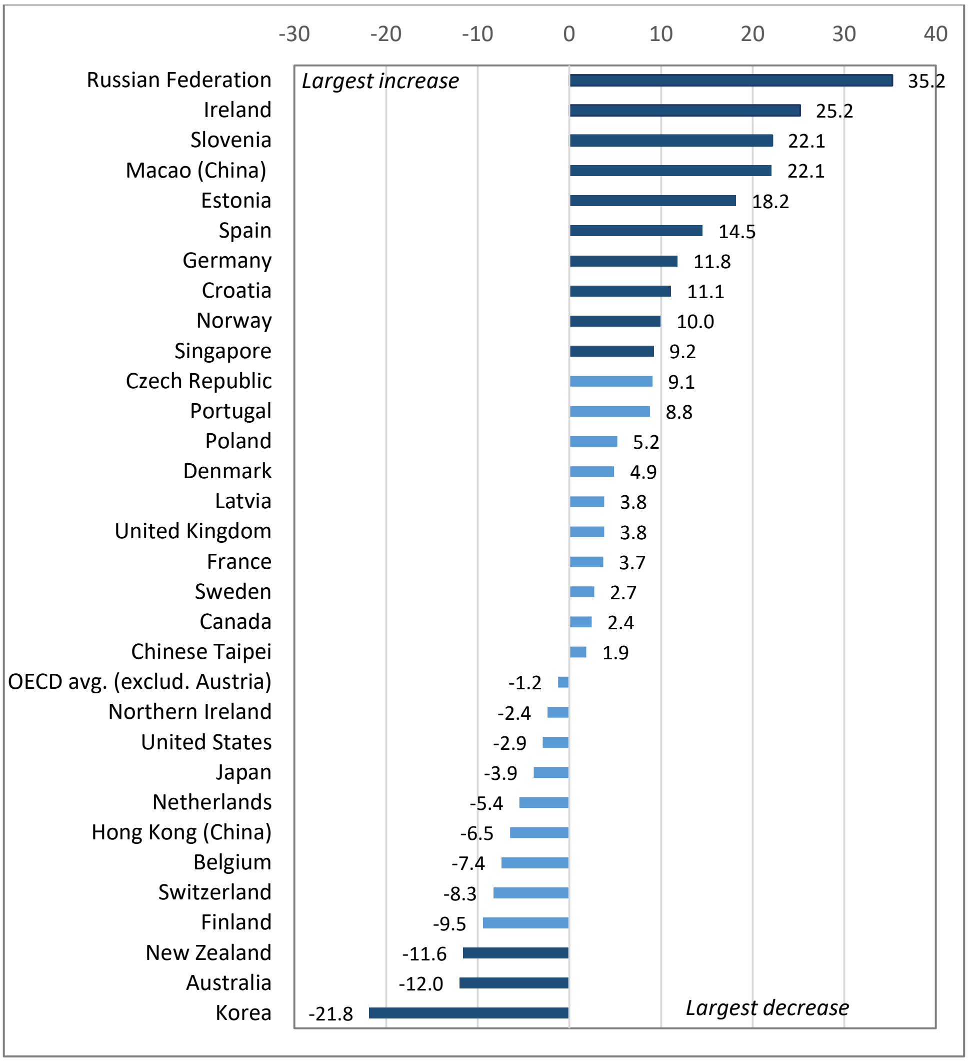


OECD average excludes Austria.

Ireland's average 3-year difference in reading literacy between 2009 and 2015 (+12.8) was statistically significant. This essentially reflects the large increase in performance between 2009 and 2012. The average 3-year difference across OECD countries was a non-significant -0.6 (E-Appendix Table A8.6).

Ireland's mean score on overall reading literacy increased significantly between 2009 and 2015 (by 25.2 score points). Nine additional countries that were among the top 30 in 2015 also had increases between 2009 and 2015. These include the Russian Federation (+35.2), Slovenia (+22.1), Macao (China) (+22.1), Estonia (+18.2), Spain (+14.5) and Norway (+10.0) (Figure 8.7). In contrast, just three countries experienced negative achievement differences: Korea (-21.8), Australia (-12.0), and New Zealand (-11.6). Finland recorded a non-significant decline of -9.5 points between these years. Performance in Northern Ireland dropped by a non-significant 2.4 score points.

Figure 8.7. Mean score differences in reading literacy between 2009 and 2015 for the top 30 performing countries/economies in 2015 that participated in PISA 2009 and PISA 2015, the average OECD difference, and the difference in Northern Ireland

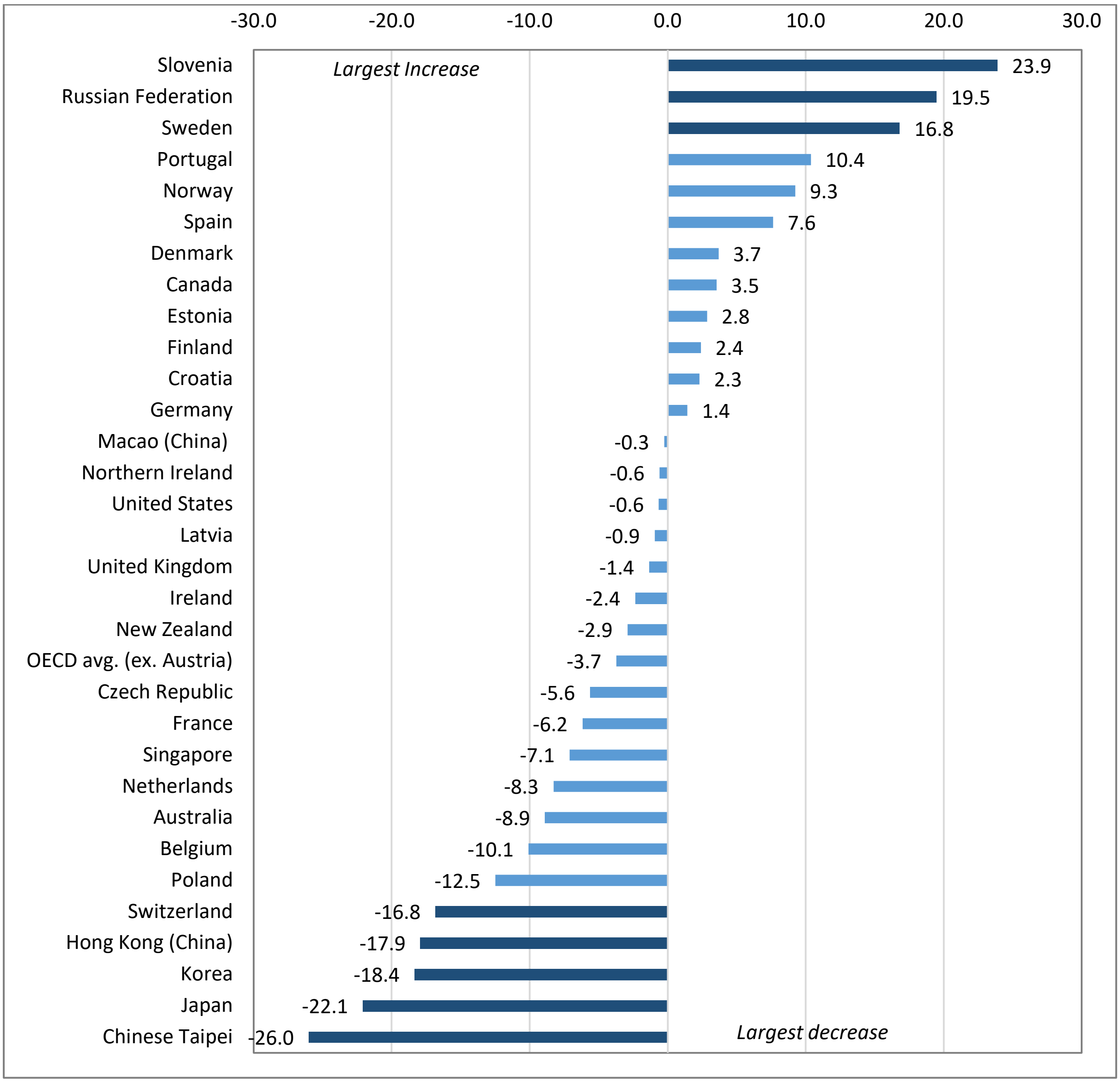


Significant difference are in bold.

As noted above, Ireland recorded a small and non-significant drop in reading literacy between 2012 and 2015 (-2.4 points). Figure 8.8 shows that three countries recorded significant increases between these years – Slovenia (+23.9), the Russian Federation (+19.5), and Sweden (+16.8). A number of countries recorded non-significant positive changes in performance, including Portugal (+10.4), Norway (+9.3), and Spain (+7.6). Five countries recorded significant declines in performance, including Chinese Taipei (-26.0), Japan (-22.1), Korea (-18.4), Hong Kong (China) (-17.0), and Switzerland (-16.8). Northern Ireland's mean score was lower in 2015 than in 2012 by a non-significant 0.6 score points.

It is noteworthy that out of the eleven countries including Ireland that recorded significant declines in science between 2012 and 2015 (Figure 8.3) Korea and Hong Kong (China) were the only ones that recorded significant declines in reading literacy between the same years.

Figure 8.8. Mean score differences in reading literacy between 2012 and 2015 for the top 30 performing countries/economies in 2015 that participated in PISA 2012 and PISA 2015, the OECD average difference, and the difference in Northern Ireland



Significant differences are in bold.

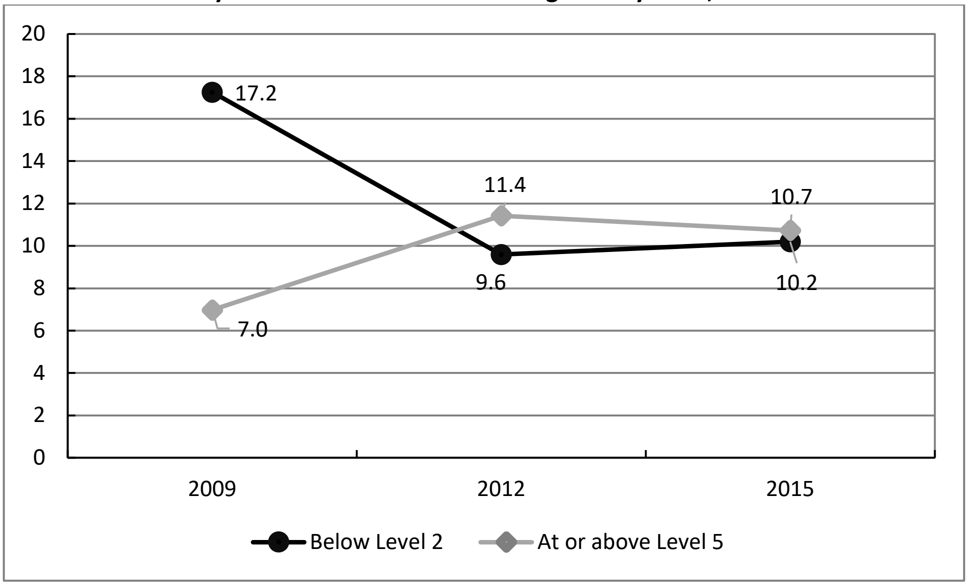
As noted in Chapter 2, Ireland's mean score on digital reading in PISA 2012 was 520.1 (on a scale with an OECD average of 496.9, and a standard deviation of 94.4). Hence, Ireland's performance in 2015 on computer-based reading literacy (comprising paper-based items from earlier PISA cycles) was about the same as in 2012 on digital literacy (comprising items that required students to engage with digital spaces such as websites and emails).

8.2.2. Trends on reading literacy proficiency levels

In 2009, 17.2% of students in Ireland performed below Proficiency Level 2 on reading literacy. This dropped significantly to 9.6% in 2012 and increased slightly to 10.2% in 2015 (Figure 8.9 and E-Appendix Table A8.7). The estimates for 2012 and 2015 are broadly in line with cycles of PISA prior to 2009 (see Chapter 2). In 2009, 7% of students in Ireland performed at or above Level 5, increasing significantly to 11.4% in 2012, and falling slightly to 10.7% in 2015. Again, the latter two are in line with the percentages achieving at or above Level 5 in 2003 and 2006, but below the percentage in 2000 (14.2%).

While the percentages of students in Ireland performing below Level 2 and at or above Level 5 did not differ from the corresponding OECD average percentages in 2009, the percentages below Level 2 were lower than the corresponding OECD average estimates in 2012 and 2015 (E-Appendix Table A8.7). Similarly, while the percentage at or above Level 5 in 2009 did not differ from the corresponding OECD average in that year, the percentages for 2012 and 2015 were higher.

Figure 8.9. Percentage of students in Ireland performing below Proficiency Level 2 and at or above Proficiency Level 5 on the overall reading literacy scale, 2009 to 2015



8.2.3. Trends in performance at key percentile markers and variation in reading literacy performance

In 2009, students at the 10th percentile in Ireland on reading literacy achieved a score of 373.4. This increased to 410.2 in 2012, but slipped back a little to 406.4 in 2015. On average across OECD countries, students at the 10th percentile achieved a score of 370.5 in 2009. This increased marginally to 372.0 in 2012, but fell back to 364.2 in 2015. While the score at the 10th percentile in Ireland was not significantly different from the average score across OECD countries at this benchmark in 2009, it was significantly higher in both 2012 and 2015.

In 2009, students at the 90th percentile in Ireland achieved a score of 610.6. This increased to 631.5 in 2012, but slipped back a little to 628.6 in 2015 (Table 8.6). On average across OECD countries, students at the 90th percentile achieved a score of 609.4 in 2009, 613.1 in 2012 and 612.8 in 2015. Hence, compared with Ireland, scores at this benchmark moved within a narrower range. Again, while the score at the 90th percentile in Ireland in 2009 was not significantly different from the corresponding OECD average, it was significantly higher in 2012 and 2015. Students in Ireland also had significantly higher average scores at both the 10th and 90th percentiles in 2012, compared with the corresponding OECD averages, reflecting increased performance in Ireland between 2009 and 2012.

Table 8.6. Comparisons of scores of students performing at the 10th and 90th percentiles on the reading literacy scale in Ireland and on average across OECD countries, 2009-2015

	Ireland				OECD			
	10th Percentile		90th Percentile		10th Percentile		90th Percentile	
	Score	SE	Score	SE	Score	SE	Score	SE
2009	373.4	(4.68)	610.5	(2.79)	370.5	(0.82)	609.4	(0.57)
2012	410.2	(5.67)	631.5	(3.17)	372.0	(0.86)	613.1	(0.61)
2015	406.4	(4.09)	628.6	(2.81)	364.2	(0.78)	612.8	(0.59)
	Diff	SED	Diff	SED	Diff	SED	Diff	SED
2015-2009	**33.0**	(7.10)	**18.1**	(5.24)	-6.3	(3.61)	3.4	(3.53)
2015-2012	-3.8	(8.74)	-2.8	(6.75)	-7.8	(5.38)	-0.3	(5.32)
	average 3-year trend in percentiles across PISA assessments							
2000-2015	**16.7**	(3.25)	**9.5**	(2.29)	-3.1	(0.98)	1.7	(0.79)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

The standard deviation on overall reading literacy in Ireland dropped from 95.1 in 2009 to 86.1 in 2012 and 86.2 in 2015 (Table 8.7). Similarly, the inter-decile range dropped from 237.1 in 2009 to 221.2 in 2012 and increased slightly to 222.2 in 2015. On average across OECD countries, the standard deviation increased by 3.4 points between 2009 and 2015, while the inter-decile range increased from 238.9 to 248.6. Hence, while variability in Ireland decreased between 2009 and 2015, it increased on average across OECD countries.

Table 8.7. Variation in reading literacy in Ireland and on average across OECD countries, 2009-2015

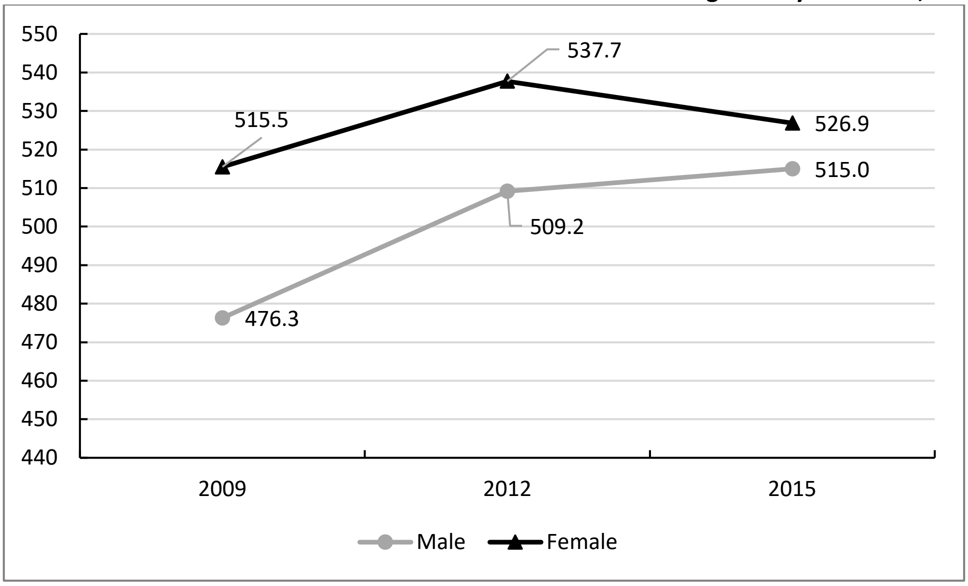
	Ireland				OECD			
	Standard deviation		Inter-decile range (90th minus 10th percentile)		Standard deviation		Inter-decile range (90th minus 10th percentile)	
	SD	SE	Score diff.	SED	SD	SE	Score diff.	SED
2009	95.1	2.18	237.1	4.72	92.5	0.29	238.9	0.89
2012	86.1	1.71	221.2	5.87	94.2	0.31	241.1	0.94
2015	86.2	1.47	222.2	4.16	95.9	0.27	248.6	0.86
	Diff	SE	Diff	SED	Diff	SE	Diff	SED
2015-2009	**-9.0**	2.6	**-14.9**	6.3	**3.4**	0.40	**9.7**	1.24
2015-2012	0.0	2.3	1.0	7.2	**1.7**	0.41	**7.5**	1.28

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

8.2.4. Trends in reading literacy by gender

In 2009, the mean score of female students in Ireland was 515.5. This increased to 537.7 in 2012, but dropped back to 526.9 in 2015 (Figure 8.10, E-Appendix Table A8.8). Mean scores for male students followed a more linear trajectory, moving from 476.3 in 2009 to 509.2 in 2012 and 515.0 in 2015. Hence, while females improved by 11.5 points between 2009 and 2015, male students improved by 38.7 (E-Appendix Table A8.8). The gender difference in favour of females was 39.2 points in 2009, 28.5 in 2012, and 12.0 in 2015. On average across OECD countries, the gender difference in favour of females fell from 39.3 points in 2009 to 27.1 points in 2015 (OECD, 2016b,Table 1.4.6d).

Figure 8.10. Mean scores of male and female students on overall reading literacy in Ireland, 2006- 2015



Gender differences can also be examined with reference to proficiency levels. In Ireland, the percentage of male students performing below Level 2 dropped from 23.1% in 2009 to 13.0% in 2012, and fell slightly to 12.3% in 2015 (Table 8.8). The percentage of females performing below Level 2 dropped from 11.2% in 2009 to 6.1% in 2012, but then increased to 8.0% in 2015. The percentage of male students performing at or above Level 5 increased from 4.5% in 2009 to 8.5% in 2012, and improved to 10.7% in 2015. The percentage of females performing at or above Level 5 increased from 9.5% in 2009 to 14.5% in 2012, but then fell back to 10.7% in 2015 – the same as the percentage of males performing at or above Level 5.

Table 8.8. Percentage of male and female students below Proficiency Level 2 and at or above Proficiency Level 5 on the reading scale in Ireland, 2009 and 2015

	Below Level 2				At or above Level 5			
	Male		Female		Male		Female	
	%	SE	%	SE	%	SE	%	SE
2009	23.1	(1.70)	11.2	(1.00)	4.5	(0.65)	9.5	(0.88)
2012	13.0	(1.35)	6.1	(0.85)	8.5	(0.74)	14.4	(1.03)
2015	12.3	(1.08)	8.0	(0.84)	10.7	(0.88)	10.7	(0.99)
	Diff	SED	Diff	SED	Diff	SED	Diff	SED
2015-2009	**-10.9**	(2.20)	**-3.2**	(1.34)	**6.2**	(1.29)	1.2	(1.66)
2015-2012	-0.8	(2.5)	2.0	(1.4)	2.2	(2.0)	-3.7	(2.6)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

On average across OECD countries, the percentage of male students performing at or below Level 2 dropped slightly between 2009 (24.7%) and 2015 (24.4%) (E-Appendix Table A8.9), while the percentage of females increased significantly from 12.2% to 15.5%. The percentages of males performing at or above Level 5 increased from 5.2% to 6.8% between 2009 and 2015, while the percentage of females remained the same in both years (9.0%). Hence, the pattern of performance by males and females in Ireland between 2012 and 2015 resembles what was observed on average across OECD countries between 2009 and 2015 – roughly similar proportions of males performing below Level 2, and a small increase in the proportion of males performing at or above Level 5, along with a slightly larger decline in the proportions of females performing at or above Level 5.

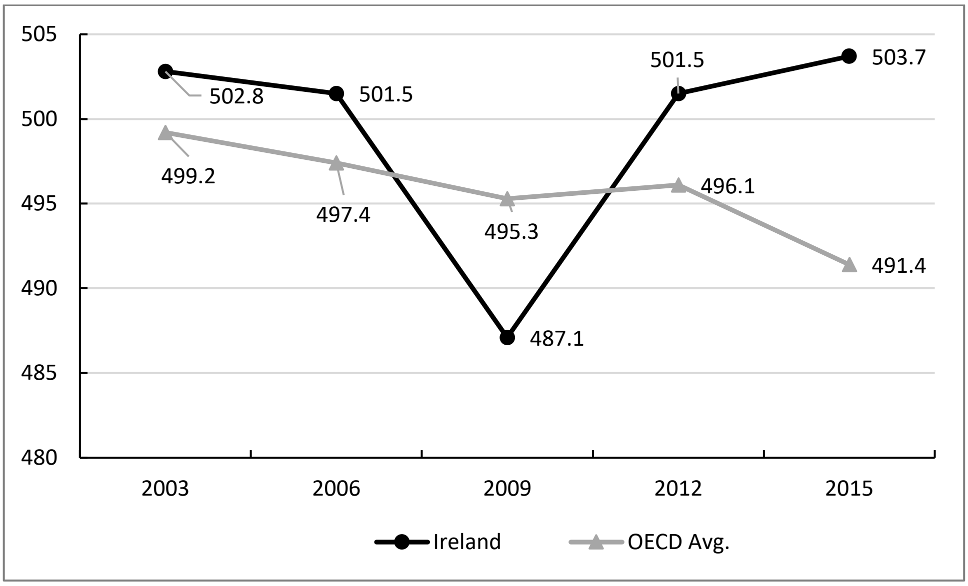
8.3. Trends in Mathematics Performance

As with reading literacy, mathematics was a minor assessment domain in 2015, having been a major domain in 2003 and again in 2012. Hence, comparisons of performance between 2012 and 2015 are especially relevant. No data on performance on subscales are available for 2015. As in the case of reading literacy, there was an increase in 2015 in the number of trend items drawn from earlier assessments. In 2009, when mathematics was also a minor domain, there were 35 trend items, compared with 69 in 2015. The increase was implemented with a view to improving construct coverage (the numbers of items representing different content areas and processes), and hence the stability of trend scores.

8.3.1. Trends in overall mathematics mean scores

Students in Ireland achieved a mean mathematics score of 502.8 in 2003 and 501.5 in 2006. As with reading literacy (but not science), performance dropped significantly in 2009, when the mean score was 487.1. There was an improvement again in 2012 (501.5), and the mean score in 2015 was 503.7. Hence, in all cycles except 2009, Ireland's mean score in mathematics ranged between 501.5 and 503.7 (Figure 8.11). Furthermore, while performance in Ireland in 2003, 2006 and 2012 was not significantly different from 2015, performance in 2009 was significantly lower (E-Appendix Table A8.10).

Figure 8. 11. Mean scores on overall mathematics scale in Ireland and on average across OECD countries, 2003-2015



OECD data are based on countries that participated in PISA 2003 and subsequent cycles, except for 2009, which draws on the value for countries in PISA 2009 and 2015.

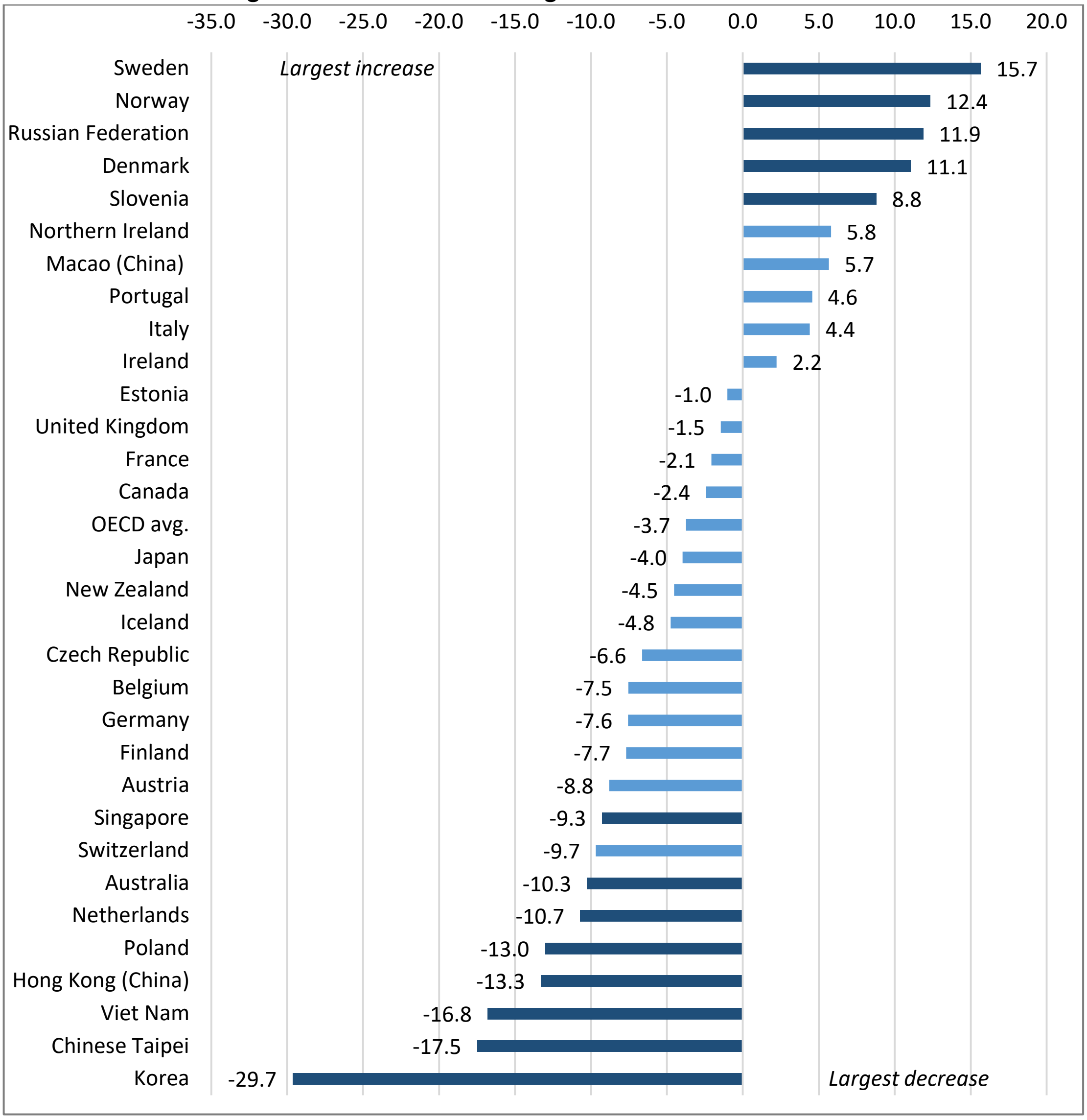
On average across OECD countries, performance dropped significantly from 499.2 in 2003 to 491.4 in 2015, among those countries that participated in PISA 2003 and PISA 2015, and for which valid data were available for both years (E-Appendix Table A8.10). In 2009, Ireland's mean score was significantly below the corresponding OECD average, while in 2012 and 2015 it was significantly above it.

The average three-year trend in mathematics (since 2003) is just 0.1 points. The corresponding average for OECD countries since 2003 is -1.7 score points (E-Appendix Table A8.10).

Figure 8.12 gives the mean score differences on mathematics between 2012 and 2015 for the 30 top-performing countries in PISA 2015, the OECD average difference and the difference for Northern Ireland. Five countries experienced a significant improvement: Sweden (+15.7 points), Norway (+12.4), the Russian Federation (+11.9), Denmark (+11.1), and Slovenia (+8.8). Northern Ireland's score difference increased by 5.8 score points, but this was not statistically significant.

Eight countries had significant declines in performance between 2012 and 2015 including Korea (-29.7), Hong-Kong (China) (-13.3), Poland (-13.0), the Netherlands (-10.7), Australia (-10.3), and Singapore (-9.3). On average across OECD countries that participated in both PISA 2012 and 2015, there was a non-significant drop in performance (-3.7)

Figure 8.12. Mean score difference in mathematics between 2012 and 2015 for the top 30 performing countries/economies on PISA 2015 mathematics that participated in PISA 2012 and PISA 2015, the OECD average difference and the average difference in Northern Ireland



Significant differences are in bold.

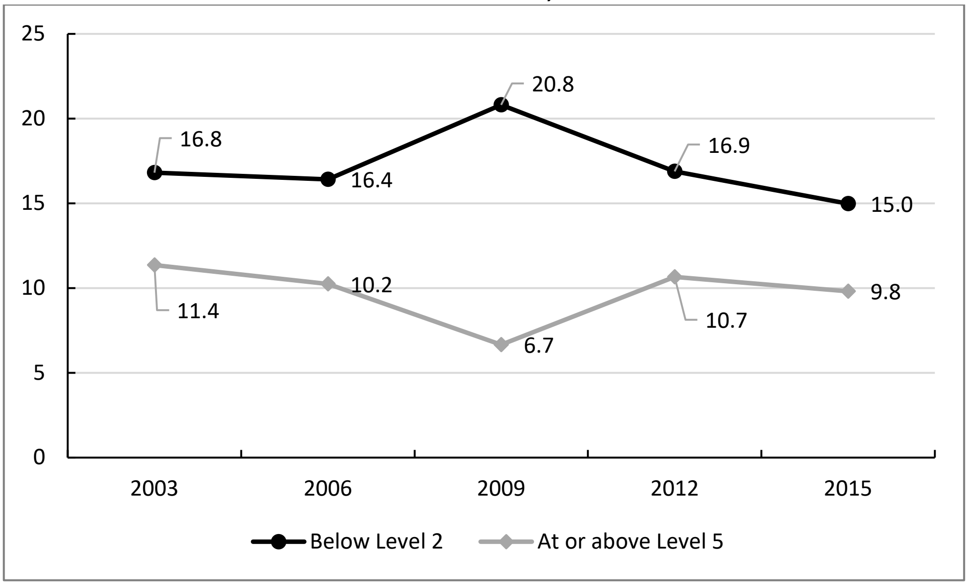
8.3.2. Trends in mathematics proficiency levels

In Ireland, 16.8% of students performed below Proficiency Level 2 in mathematics in 2003, and roughly equivalent percentages of students performed at this level in subsequent cycles, except 2009, when 20.8% performed below Level 2 (Figure 8.13). In 2015, 15% of students in Ireland performed below Level 2, but this was not statistically significantly different from 2003 (16.8%), or indeed 2012 (16.9%). On average across OECD countries, 21.6% performed below Level 2 in 2003, and this rose to 22.9% in

2015 – the highest percentage across PISA cycles, but not significantly different from any of the earlier cycles (E-Appendix Table A8.11).

In 2003, 11.4% in Ireland performed at or above Level 5, and roughly equivalent percentages performed at this level in subsequent cycles, except in 2009 when 6.7% performed at or above Level 5 (Figure 8.13). In 2015, 9.8% in Ireland performed at or above Level 5, and this percentage was not significantly different from 2003, or indeed 2012 (10.7%). On average across OECD countries, the percentage performing at or above Level 5 dropped from 14.4% in 2003 to 10.8% in 2015. Moreover, a significantly lower percentage of students on average across OECD countries performed at or above Level 5 in 2015, compared with each previous cycle (E-Appendix Table A8.11).

Figure 8.13. Percentage of students below Proficiency Level 2 and at or above Proficiency Level 5 on overall mathematics in Ireland, 2009-2015



8.3.3. Trends in performance at key percentile markers and variation in mathematics literacy performance

The score of students in Ireland at the 10th percentile on overall mathematics increased from 393.1 in 2003 to 399.8 in 2015, despite a dip to 376.1 in 2009. The difference between scores at this marker in 2012 (391.0) and 2015 (399.8) is not statistically significant (Table 8.9). On average across OECD countries, performance at the 10th percentile was broadly similar across cycles with a high in 2006 (379.4) and a low in 2015 (373.8). The difference between these years (5.6) was statistically significant.

The score of students in Ireland at the 90th percentile was 613.9 in 2003. This dropped to 590.6 in 2009, but improved to 609.8 in 2012, before falling back to 606.1 in 2015. On average across OECD countries, performance at the 90th percentile fell from 619.0 in 2003 to 605.6 in 2015. Performance at the 90th percentile in each previous PISA cycle was significantly higher than in 2015 (Table 8.9).

Table 8.9. Comparisons of percentage of students performing at the 10th and 90th percentiles on the mathematics scale in Ireland and on average across OECD countries, 2012-2015

	Ireland				OECD			
	10th Percentile		90th Percentile		10th Percentile		90th Percentile	
	%	SE	%	SE	%	SE	%	SE
2003	393.1	(3.21)	613.9	(3.59)	377.6	(0.83)	619.0	(0.85)
2006	396.1	(4.39)	607.7	(3.16)	379.4	(0.86)	614.2	(0.79)
2009	376.1	(4.37)	590.6	(3.08)	376.5	(0.75)	612.0	(0.71)
2012	391.0	(3.63)	609.8	(2.46)	377.1	(0.72)	615.3	(0.76)
2015	399.8	(3.80)	606.1	(2.59)	373.8	(0.71)	605.6	(0.64)
	Diff	SED	Diff	SED	Diff	SED	Diff	SED
2015-2003	6.8	(7.49)	-7.8	(7.15)	-3.8	(5.71)	**-13.4**	(5.71)
2015-2006	-3.7	(5.81)	-1.60	(4.09)	**-5.6**	1.12	**-8.60**	(1.02)
2015-2009	**23.7**	5.79	**15.50**	4.02	-2.7	1.03	**-6.40**	0.96
2015-2012	8.9	(6.34)	-3.7	(5.04)	-3.2	(3.69)	**-9.6**	(3.68)
	Average 3-year trend in percentiles across PISA assessments							
	0.8	(1.57)	-1.5	(1.43)	-1.0	(1.16)	**-2.6**	(1.16)

Significant differences in bold. OECD data are based on countries that participated in PISA 2003 and subsequent cycles, except for 2009, which draws on the value for countries in 2009 and 2015.

In Ireland, the standard deviation fell significantly from 85.3 in 2003 to 79.8 in 2015 (Table 8.10). The average standard deviation across OECD countries also fell significantly between these two years, from 93.4 to 89.4. The inter-decile ranges in Ireland and on average across OECD countries also fell between 2003 and 2015, by 14.6 and 9.6 points respectively, again indicating a narrowing in achievement. Importantly, in Ireland and on average across OECD countries, standard deviations and inter-decile ranges narrowed significantly between 2012 and 2015.

Table 8.10. Variation in mathematics in Ireland and on average across OECD countries, 2009-2015

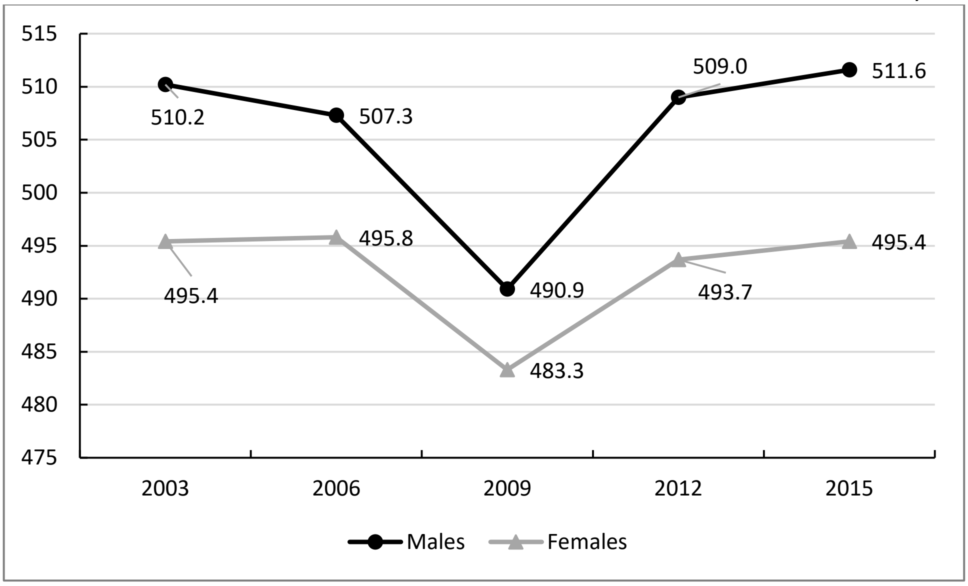
	Ireland				OECD			
	Standard deviation		Inter-decile range (90th minus 10th percentile)		Standard deviation		Inter-decile range (90th minus 10th percentile)	
	SD	SE	Score diff.	SED	SD	SE	Score diff.	SED
2003	85.3	(1.26)	220.8	(4.21)	93.4	(0.35)	241.4	(1.05)
2006	82.0	(1.50)	211.6	(4.64)	91.3	(0.37)	234.9	(1.05)
2009	85.6	(1.59)	214.5	(4.58)	91.2	(0.30)	235.5	(0.91)
2012	84.6	(1.26)	218.8	(3.63)	91.7	(0.29)	238.2	(0.91)
2015	79.8	(1.38)	206.3	(4.23)	89.4	(0.28)	231.8	(0.86)
	Diff	SE	Diff	SED	Diff	SE	Diff	SED
2015-2003	**-5.5**	(1.86)	**-14.6**	(5.97)	**-4.0**	(0.45)	**-9.6**	(1.36)
2015-2006	-2.20	(2.04)	-5.3	(6.28)	-1.80	(0.41)	**-3.7**	(1.25)
2015-2009	**5.8**	(2.11)	8.2	(6.23)	-3.80	(1.61)	**-4.0**	(1.21)
2015-2012	**-4.8**	(1.87)	**-12.5**	(5.57)	**-2.3**	(0.40)	**-6.4**	(1.25)

Significant differences in bold. OECD data based on countries that participated in PISA 2003 and subsequent cycles, except 2009, which draws on the value for countries in 2009 and 2015. SE = standard error; SED = standard error of the difference.

8.3.4. Trends in mathematics performance by gender

In all but one PISA cycle since 2003, male students in Ireland achieved significantly higher mean mathematics scores than female students (Figure 8.14). In 2009, a difference of 7.5 points in favour of males was not statistically significant (see E-Appendix Table A8.12 and Perkins et al., 2012). The difference was greatest (16.1 points) in 2015. However, while males improved by 2.5 points between 2012 and 2015, and females improved by 1.7 points, neither change was statistically significant (E-Appendix Table 8.12). Average gender differences across OECD countries have also favoured male students over females. Differences have been similar in size across cycles (10.4 points in 2003, 11.2 in 2006, 11.5 in 2009, and 10.3 in 2012). In 2015, the difference in favour of males dropped to 7.7, but was still statistically significant (see E-Appendix Table A8.13 and OECD, 2016b, Tables 1.5.6d, I.5.6e).

Figure 8.14. Mean scores of male and female students on the overall mathematics in Ireland, 2006 to 2015



Gender differences can also be examined with reference to proficiency levels. In 2003, 15.0% of male students in Ireland performed below Level 2, and this percentage dropped to 14.1% by 2015. However, the differences between 2003 and 2015, and between 2012 and 2015 are not statistically significant (Table 8.11). The percentage of female students in Ireland performing below Level 2 dropped from 18.7% in 2003 (and 2012) to 15.8% in 2015. Again, however, neither the difference between 2003 and 2015, nor the difference between 2012 and 2015, is statistically significant.

The percentages of male students in Ireland performing at or above Level 5 declined from 13.7% in 2003 to 12.9% in 2015, while the percentage of females declined from 9.0% to 6.5% between the same years (Table 8.11). However, differences between 2003 and 2015, and between 2012 and 2015, are not statistically significant for either gender.

Table 8.11. Percentage of male and female students below Proficiency Level 2 and at or above Proficiency Level 5 on the mathematics scale in Ireland, 2003- 2015

	Below Level 2				At or above Level 5			
	Male		Female		Male		Female	
	%	SE	%	SE	%	SE	%	SE
2003	15.0	(1.35)	18.7	(1.36)	13.7	(1.11)	9.0	(0.98)
2012	15.2	(1.41)	18.7	(1.24)	12.7	(0.88)	8.5	(0.71)
2015	14.1	(1.17)	15.8	(1.01)	12.9	(0.96)	6.5	(0.80)
	Diff	SED	Diff	SED	Diff	SED	Diff	SED
2015-2003	-0.8	(3.11)	-2.8	(3.90)	-0.8	(2.64)	-2.5	(1.78)
2015-2012	-1.0	(2.06)	-2.8	(2.13)	0.2	(1.54)	-2.0	(1.18)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

On average across OECD countries, the percentage of male students performing below Level 2 increased marginally from 20.9% in 2003 to 21.5% in 2012 and to 22.6% in 2015, while the percentage of female students performing below Level 2 increased slightly from 22.2% in 2003 to

22.9% in 2012 and to 23.2% in 2015 (E-Appendix Table A8.14). On the other hand, there were relatively large declines in the percentages performing at or above Level 5. In 2003, 16.6% of male students on average across OECD countries performed at or above Level 5, and this dropped to 14.9% in 2012 and dropped further to 12.6% in 2015. Similarly, the percentage of female students who performed at or above Level 5 was 12.3% in 2003 and this dropped to 10.8% in 2012 and 9.0% in 2015. Hence, by 2015, fewer male and female students in Ireland than on average across OECD countries were performing below Level 2, and, while similar proportions of males in Ireland and on average across OECD countries were performing at or above Level 5 (12.6% and 12.3% respectively), fewer female students in Ireland (6.5%) were performing at or above Level 5, compared with the corresponding OECD average (9.0%).

8.4. Trends in Performance Related to School and Student Factors

This section examines some broad trends in key factors related to performance at the school and student levels. These include school gender composition and school status under DEIS at the school level, and current grade level and language spoken at home at the student level. Two further subsections examine performance on the Junior Certificate examination and the adjustment of mean scores by the OECD to account for demographic changes over time.

8.4.1. Trends in school characteristics and performance

Variation in achievement (and other variables) can be separated into between-school and within-school components. Between-school variance, expressed as a percentage of total variance, is an indication of the extent to which schools differ with respect to average achievement. Between-school variance on science has dropped from 19.6% in 2012 to 14.1% in 2015, while, for reading literacy, it has dropped from 24.1% to 13.3% between the same years (Table 8.12). The change for mathematics was from 19.3% to 15.2%. These data suggest that, in 2015 (compared with 2012) schools are more similar to one another in terms of performance.

Table 8.12. Between-school variance in achievement (expressed as a percentage of total variance), for science, reading literacy and mathematics in Ireland (2006-2015)

Domain	2006	2009	2012	2015
Science	17.7	25.0	19.6	14.1[38]
Reading literacy	24.2	25.0	24.1	13.3
Mathematics	20.0	23.5	19.3	15.2

Estimates of between-school variance computed using HLM 6.0.

Table 8.13 compares performance by school gender composition in the two cycles in which science has been a major assessment domain in PISA. This shows that, while performance in science dropped in all school types, the decline was greatest in girls' secondary schools, where there was a drop of 11.4 score points, though this was not significant. There was a drop of 6.6 score points in community/comprehensive schools, and this also was not statistically significant either. In general, the proportions of students who attended schools with differing gender compositions were similar across the two cycles, though marginally more students attended vocational schools in 2015 (26.0%) than in 2006 (23.6%).

[38] In Chapter 6, an estimate of 11.5% for between-school variation in science in Ireland was reported. This figure, which was provided by the OECD, is the variance between schools in Ireland as a percentage of the average total variance across OECD countries. The data in Table 8.12 are not benchmarked against average total variation across OECD countries.

Table 8.13. Change in mean science scores in Ireland by school sector and gender composition, 2006-2015

	2006			2015			Difference 2015-2006	
	%	Mean	SE	%	Mean	SE	Mean	SED
Girls' Secondary	22.6	522.6	(5.02)	21.1	511.2	3.58	-11.4	(6.17)
Boys' Secondary	18.1	525.4	(8.10)	16.7	521.7	5.52	-3.7	(9.80)
Community/Comprehensive	16.8	501.3	(6.47)	17.6	494.7	3.89	-6.6	(7.55)
Mixed Secondary	19.0	515.7	(6.40)	18.6	510.3	6.49	-5.4	(9.11)
Vocational	23.6	480.7	(7.09)	26.0	483.1	5.69	-2.4	(9.09)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

Table 8.14 shows the performance of students in different school types in 2012 and in 2015. There were declines in performance in all school types, with the largest in vocational schools (-24.8) and community/comprehensive schools (-21.0). While the size of the decline in girls' secondary and boys' secondary schools was about the same (-15.0 and -15.5 respectively), the decline was statistically significant in girls' secondary schools only.

Table 8.14. Change in mean science scores in Ireland by school sector and gender composition, 2012-2015

	2012			2015			Difference 2015-2012	
	%	Mean	SE	%	Mean	SE	Mean	SED
Girls' Secondary	21.6	526.2	6.22	21.1	511.2	3.58	**-15.0**	7.18
Boys' Secondary	16.2	537.2	7.27	16.7	521.7	5.52	-15.5	9.13
Community/Comprehensive	16.8	515.7	5.82	17.6	494.7	3.89	**-21.0**	7.00
Mixed Secondary	20.3	528.1	4.96	18.6	510.3	6.49	**-17.8**	8.17
Vocational	25.1	507.9	5.80	26.0	483.1	5.69	**-24.8**	8.13

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

Taken together, Tables 8.13 and 8.14 suggest that, although overall science performance in Ireland increased between 2006 and 2012, the increase impacted to a lesser extent on girls' secondary schools, compared with other school types the mean score of students in these schools also fell in 2015. Indeed, performance declined further in all school types between 2012 and 2015, though not significantly in boys' secondary schools.

E-Appendix Tables A8.15 and A8.16 show that there were no significant changes in performance in reading literacy or mathematics across schools of differing sector and gender composition in 2012-2015.

In 2006, students in non-disadvantaged[39] schools achieved a mean score (517.9) that was significantly higher, by 38.1 score points, than the mean score of students in disadvantaged schools (479.8) (Eivers et al., 2006). As noted in Chapter 6, the respective scores of students attending non-SSP and SSP schools in 2015 are 510.3 and 462.0, respectively. Again, the gap, 48.3 score points difference in favour of students attending non-SSP/DEIS schools, is statistically significant.

[39] Although DEIS was launched in 2005, schools in the PISA 2006 sample were still categorised according to their participation in the pre-DEIS disadvantaged schools scheme.

8.4.2. Trends in student-level characteristics

Table 8.15 shows that, between 2006 and 2015, when Ireland's overall mean science score dropped by a non-significant 5.8 score points, performance on PISA science was stable at Third year, but declined significantly in Transition year (-17.1 points) and in Fifth year (-33.7 points). Changes in performance in Transition year and Fifth year may reflect demographic changes at those grade levels between 2006 and 2015, with an increase in the percentage of students in Transition year (from 21.2% to 26.7%, including students who, in the past, might have gone on to Fifth year after Junior Certificate), and a proportionate decline in the percentage in Fifth year (from 17.5% to 10.9%).

Table 8.15. Change in mean science scores in Ireland, by grade level, 2006-2015

		2006			2015		Diff 2015-2006	
	%	Mean	SE	%	Mean	SE	Mean Diff	SED
Second Year	2.7	408.5	(11.0)	1.9	427.8	(9.83)	19.3	14.75
Third Year	58.6	499.3	(3.50)	60.5	500.7	(2.48)	1.4	4.29
Transition Year	21.2	537.1	(4.30)	26.7	520.0	(3.80)	-17.1	5.74
Fifth Year	17.5	519.6	(4.30)	10.9	485.9	(5.13)	-33.7	6.69

Significant differences are in bold. SE = standard error; SED = standard error of the difference. Categorisation by grade level is based on weighted national data, and differs from the unweighted data in Table 1.10 (which were provided by the OECD).

In the period 2012-2015, when Ireland's overall mean score on science dropped by a significant 19.4 score points, there were significant declines in performance at Third, Transition and Fifth Years (Table 8.16), with the largest decline occurring at Fifth year (-32.4) (Table 8.16).

Table 8.16. Change in mean science scores in Ireland, by grade level, 2012-2015

		2012			2015		Diff 2015-2006	
	%	Mean	SE	%	Mean	SE	Mean Diff	SED
Second Year	1.9	458.3	(11.58)	1.9	427.8	(9.83)	-30.5	15.19
Third Year	60.5	516.3	(2.68)	60.5	500.7	(2.48)	**-15.6**	3.65
Transition Year	24.3	543.3	(3.97)	26.7	520.0	(3.80)	**-23.3**	5.50
Fifth Year	13.3	518.3	(5.46)	10.9	485.9	(5.13)	**-32.4**	7.49

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

There were significant increases in reading literacy at all grade levels except Fifth year, between 2009 and 2015, while, for mathematics, there were no significant changes across any of the grade levels between 2012 and 2015 (E-Appendix Tables A8.17 and A8.18).

Table 8.17 shows that, between 2006 and 2015, the proportion of native students (as defined in Chapter 6) declined from 94.6% to 85.6%. Although their science performance dropped by 5.3 score points between those years, the difference was not statistically significant. Science performance dropped by a non-significant 20.8 points among immigrant students who spoke English or Irish at home – a group whose representation in PISA doubled between 2006 and 2015, from 3.6% of students to 7.3%. The effect of this was to align more closely the performance of native and immigrant students with English or Irish by 2015 (their mean scores in that year were 505.1 and 507.9 points respectively). The performance of immigrant students with a language other than English or Irish improved significantly between 2006 and 2015, by 45.7 score points.

Table 8.17. Change in mean science scores of students in Ireland, by immigrant/language status, 2006-2015

	2006			2015			Difference 2015-2006	
	%	Mean	SE	%	Mean	SE	Mean	SED
Native	94.6	510.4	(2.99)	85.6	505.1	(2.50)	-5.30	3.90
Immigrant with English or Irish	3.6	528.7	(9.67)	7.3	507.9	(5.34)	-20.8	11.05
Immigrant with other language	1.7	447.2	(24.4)	7.1	492.9	(5.22)	**45.7**	8.81

Significant differences in bold. SE = standard error; SED = standard error of the difference.

Between 2012 and 2015, there were declines in science performance among native students, immigrant students who spoke English or Irish at home, and immigrant students who spoke a different language. These declines (-19.0, -26.5 and 23.2 score points, respectively) are broadly in line with the overall decline in science performance in Ireland of 19.4 score points between these years (Table 8.18). It is also noteworthy that the percentages of immigrant students in PISA who spoke English or Irish, and those who spoke a different language, increased between 2012 and 2015.

Table 8.18. Change in mean science scores of students in Ireland, by immigrant/language status, 2012-2015

	2012			2015			Difference 2015-2012	
	%	Mean	SE	%	Mean	SE	Mean	SED
Native	90.4	524.1	(2.47)	85.6	505.1	(2.50)	**-19.0**	3.51
Immigrant with English or Irish	5.1	534.4	(6.38)	7.3	507.9	(5.34)	**-26.5**	8.32
Immigrant with other language	4.5	516.1	(8.14)	7.1	492.9	(5.22)	**-23.2**	9.67

Significant differences in bold. SE = standard error; SED = standard error of the difference.

8.4.3. Trends in science on the Junior Certificate examination

This section looks at the representation and performance of students on the Junior Certificate science examination in 2006, 2012 and 2015, based on population statistics drawn from the State Examinations Commission website.

Between 2006 and 2015, the proportion of candidates taking Junior Certificate science (as a percentage of all Junior Certificate school-based candidates) increased from 82.6% to 91.2% (Table 8.19). In 2015, 90.5% of female candidates and 94.1% of male candidates took Junior Certificate science. While the proportion of all Junior Certificate candidates taking science increased by 4.4% between 2006 and 2015 for male students, it increased by 7.9% for females.

Table 8.19. Changes in the numbers and percentages of Junior Certificate taking science, by gender, 2006-2015

	2006			2012			2015		
	N		%	N		%	N		%
	Total JC Students	Science Students	Taking science	Total JC Students	Science Students	Taking science	Total JC Students	Science Students	Taking science
Female	28,547	23,571	82.6	28891	25210	87.3	28,891	26,136	90.5
Male	29,397	26,357	89.7	29907	27395	91.6	29,907	28,154	94.1
Total	57,944	49,928	86.2	58798	52605	89.5	59,522	54,290	91.2

Source: www.examinations.ie

Table 8.20 shows the proportions of students taking science in the Junior Certificate examination at Higher and Ordinary level at three-yearly intervals between 2006 and 2015. A feature of the data is the steady increase in the proportion of students taking Higher level, from 67.3% (combined 1989 and revised syllabi) in 2006 to 78.6% in 2015, with an increase of 2.6% between 2012 and 2015.

Table 8.20. Percentages of Junior Certificate students taking the science examination at Higher and Ordinary levels, 2006-2015

Level	2006	2009	2012	2015
Higher	67.3	70.6	76.0	78.6
Ordinary	32.7	29.4	24.0	21.4

Source: www.examinations.ie

The proportion of A and B grades awarded at Higher level has increased marginally from 39.6% in 2009 to 42.5% in 2015 (Table 8.21). While the proportion achieving grade C has remained constant across these years, the proportion achieving grade D has dropped, from 20.9% in 2009 to 18.6% in 2015. There has been a drop in the proportion achieving grades A and B at Ordinary level, from 35.5% in 2009 to 26.2% in 2015, while the proportion achieving a C grade has increased from 44.2% to 53.9%, and the proportion achieving grade D has gone up just marginally, from 15.9% in 2009 to 16.2% in 2015. In general, the proportions achieving grades E, F and NG have remained constant. Overall, the distribution of grades is similar across the examination years considered, with some adjustment at Higher level to take the declining proportion taking Ordinary level into account. There is no evidence in the data of a large decline in performance, such as that which occurred in PISA science between 2012 and 2015.

Table 8.21. Trends in Junior Certificate students science grades, by examination level, 2006-2015

			Percent Achieving Grade				
		N	A	B	C	D	E/F/NG
2006 (1989)	Higher	3,092	12.8	24.4	27.1	23.6	12.1
	Ordinary	1,724	8.4	32.3	35.6	18.7	5.0
2006 (Rev)	Higher	30,520	10.1	31.6	38.8	18.0	1.5
	Ordinary	14,592	1.1	24.2	46.6	21.7	6.3
2009	Higher	34,246	9.2	30.4	37.7	20.9	1.9
	Ordinary	14,289	2.5	33.0	44.2	15.9	4.4
2012	Higher	39,991	9.5	31.4	37.6	20.0	1.4
	Ordinary	12,615	1.6	32.9	45.9	15.8	3.8
2015	Higher	42658	10.3	32.2	37.4	18.6	1.5
	Ordinary	11632	0.6	25.6	53.9	16.2	3.7

Source: www.examinations.ie. There is a discrepancy of one student between the numbers of examination candidates in the overall distribution of science scores by grade level, and the distribution of candidates by grade level and gender for 2012. In 2006, a small number of students sat an examination based on the 1989 science syllabus, while majority sat an examination based on the 2003 (revised) science syllabus.

8.4.4. Trends on ICT usage for schoolwork

PISA 2012 asked students to respond to a number of specific questions about ICT usage in general, and ICT usage relating to mathematics. In Ireland, students had mean scores of -0.07 on use of ICT at school, -0.15 on use of ICT in mathematics lessons, and -0.60 on use of ICT at home for school-related tasks[40] (Cosgrove et al., 2014, Table 9.3). While the average scores on these indices in Ireland lagged well behind countries such as Denmark and Norway, a number of countries that tended to perform well on PISA, including Japan and Korea, also had low scores on the indices. Furthermore,

[40] The OECD average scores on these indices in 2012 was 0 and the standard deviation was 1. Mean scores vary slightly around 0 in 2015 because of the addition of a new OECD country (Latvia) to the data set after scaling of indices had been completed. There are no statistical links between the scales for 2012 and 2015.

while countries such as Finland, the Netherlands and Sweden reported strong usage of ICT in school, their use of ICT in mathematics lessons was below the OECD average.

In PISA 2015, students were not asked specific questions about use of ICT in science lessons. However, as noted in Chapter 6, students in Ireland recorded a mean score of -0.38 on an index of Use of ICT at School in general, and a mean score of -0.42 on an index of Use of ICT Outside of school for Schoolwork. Hence, ICT usage, as it relates to schoolwork, whether at school or at home, lags well behind OECD average levels in recent cycles of PISA.

More positively, while students in Ireland in PISA 2012 had low mean scores on an index the Computer as a Positive Tool for School Learning (-0.20), their counterparts in 2015 recorded a mean score that was above the OECD average on an index of Interest in ICT, though this index did not correlate positively with science performance in Ireland.

8.4.5. Adjustment of mean scores to correct for demographic changes

As part of its analysis of the PISA 2015 data, the OECD adjusted mean scores on science, reading literacy and mathematics to reflect demographic changes in the populations of participating countries since earlier cycles. The reweighting has the effect of adjusting the characteristics of past samples to the observed composition of the PISA 2015 sample. The variables taken into account in the adjustment include students' immigrant status, language spoken at home, gender, and relative age. It should be noted that demographic changes tracked by the OECD do not include the distribution of students across grade levels, and the effects of demographic changes on performance, when examined retrospectively, may be under-estimated in Ireland because of this.

Table 8.22 provides adjusted and unadjusted mean scores for Ireland, selected countries, and the average across OECD countries. In Ireland, there are small and non-significant differences between adjusted and unadjusted mean science scores across cycles. For example, the unadjusted mean score in Ireland in 2006 was 508.3, while the adjusted mean score was 506.2. This means that, if the demographic composition of the sample in 2006 had been the same as in 2015, Ireland's mean sciences score in 2006 would have been 506.2. It is likely that the small difference (which is not statistically significant) may have arisen because of changes in the proportion of non-native speakers of languages other than English or Irish in 2015, since other factors taken into account by the OECD, such as the distribution of students by gender, are broadly similar across cycles (see Chapter 2). Across cycles and countries, differences between adjusted and unadjusted scores are minimal and almost invariably within the margins of error around mean scores.

Table 8.22. Adjusted and unadjusted means scores in science in Ireland and selected countries, and on average across OECD countries, 2006-2015

		2006		2009		2012		2015	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Ireland	Adjusted	506.2	(3.74)	507.6	(3.20)	521.1	(2.49)	---	---
	Unadjusted	508.3	(3.19)	508.0	(3.27)	522.0	(2.45)	502.6	(2.39)
OECD*	Adjusted	496.0	(0.53)	499.0	(0.51)	500.3	(0.49)	---	---
	Unadjusted	497.7	(0.50)	500.8	(0.49)	501.0	(0.49)	493.2	(0.43)
Australia	Adjusted	524.7	(2.37)	524.4	(2.66)	522.6	(1.75)	---	---
	Unadjusted	526.9	(2.26)	527.3	(2.53)	521.5	(1.76)	510.0	(1.54)
Korea	Adjusted	521.5	(3.37)	538.3	(3.43)	537.5	(3.67)	---	---
	Unadjusted	522.1	(3.36)	538.0	(3.44)	537.8	(3.66)	515.8	(3.13)
Netherlands	Adjusted	524.4	(2.70)	522.0	(5.50)	521.4	(3.58)	---	---
	Unadjusted	524.9	(2.74)	522.2	(5.42)	522.1	(3.51)	508.6	(2.26)
Germany	Adjusted	507.6	(4.33)	519.3	(2.85)	524.6	(3.01)	---	---
	Unadjusted	515.6	(3.80)	520.4	(2.80)	524.1	(2.96)	509.1	(2.70)
Canada	Unadjusted	533.3	(2.13)	526.1	(1.80)	524.0	(1.97)	---	---
	Adjusted	534.5	(2.03)	528.7	(1.62)	525.4	(1.93)	527.7	(2.08)

OECD averages for 2006, 2012 and 2015 are based on countries with data for both 2006 and 2015. The OECD average for 2009 is based on countries with data for 2009 and 2015. Source: OECD (2016a), Table I.2.4e (web-based).

Table 8.23 provides adjusted and unadjusted mean scores for reading literacy and mathematics in 2009, 2012 and 2015 for Ireland and on average across OECD countries. Again, differences between adjusted and unadjusted mean scores in Ireland are relatively small. In reading literacy, in 2009, the unadjusted and adjusted scores were 494.7 and 495.6 respectively. This can be interpreted as indicating that, if the demographic composition of the sample in 2009 had been the same as in 2015, Ireland's mean score in that year would have been marginally lower, by 0.9 score points. This finding is interesting in the context of the large drop in reading literacy performance reported for Ireland in 2009.

Table 8.23. Adjusted and unadjusted means scores in reading literacy and mathematics in Ireland and on average across OECD countries, 2009-2015

			2009		2012		2015	
			Mean	SE	Mean	SE	Mean	SE
Ireland	Reading lit.	Adjusted	494.7	(2.94)	521.7	(2.56)	---	---
		Unadjusted	495.6	(2.97)	523.2	(2.55)	520.8	(2.47)
	Mathematics	Adjusted	486.5	(2.52)	500.8	(2.27)	---	---
		Unadjusted	487.1	(2.54)	501.5	(2.25)	503.7	(2.05)
OECD*	Reading lit.	Adjusted	492.3	(0.50)	495.6	(0.50)	---	---
		Unadjusted	493.8	(0.48)	496.4	(0.50)	492.8	(0.47)
	Mathematics	Adjusted	493.7	(0.50)	493.0	(0.50)	---	---
		Unadjusted	495.3	(0.49)	496.1	(0.52)	491.4	(0.48)

Reading and mathematics: OECD averages based on OECD countries in PISA 2009, PISA 2012 and PISA 2015. Source: OECD (2016b), Tables I.4.4e, I.5.5e (web-based).

8.5. Trends in Students' Attitudes, Self-beliefs, Engagement with Science, and Career Expectations

This section examines changes between 2006 and 2015 on a number of variables related to students' attitudes towards science, their engagement in science-related activities, and their aspirations for science-related careers at age 30. It looks at these variables as measured through students' responses to the PISA student questionnaire.

Table 8.24 provides mean scores on three measures based on questionnaire items that students responded to in 2006 and 2015: Enjoyment of Science (that is, intrinsic motivation), Instrumental Motivation to Learn Science, and Student Self-efficacy in Science. There were large and significant increases in Ireland between these years on Enjoyment of Science (+0.38 points) and on Instrumental Motivation (+0.21). The improvement in Enjoyment of Science is especially noteworthy as students in Ireland have moved from being significantly below the OECD average on this measure in 2006 to performing well above it in 2015. While Instrumental Motivation to learn science in Ireland was significantly above the OECD average in 2006, it is now well above that benchmark. Ireland's average score on Science Self-efficacy did not change significantly and Ireland is not significantly different from the OECD average on that measure in 2015.

Table 8.24. Mean scores and difference scores on indices of enjoyment of science, motivation to learn science, and science self-efficacy in Ireland and on average across OECD countries, 2006-2015

	2006				2015				Difference 2015-2006			
	IRL		OECD		IRL		OECD		IRL		OECD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SED	Mean	SED
Enjoy of science	-0.18	(0.02)	0.00	(0.0)	0.20	(0.02)	0.02	(0.00)	**0.38**	(0.03)	**0.01**	(0.00)
Instrum. Motiv.	0.15	(0.02)	0.01	(0.0))	0.36	(0.02)	0.14	(0.00)	**0.21**	(0.03)	**0.13**	(0.00)
Science self-eff.	0.01	(0.02)	0.00	(0.0)	0.06	(0.02)	0.04	(0.00)	0.05	(0.03)	**0.04**	(0.00)

Significant differences are in bold. SE = standard error; SED = standard error of the difference. Instrum. Motiv. = instrumental motivation; Self-eff. = self-efficacy.

Table 8.25 provides mean scores on the index of students' Engagement in Science-related Activities in Ireland and on average across OECD countries in 2006 and 2015, as well as percentages of students participating very often or regularly in various activities in these years. The mean score of students in Ireland on the index of Engagement in Science Activities in 2006 was -0.43, compared with an OECD average of 0.05. There is a marginal improvement of 0.06 points in 2015, though this still leaves Ireland well behind the OECD average of -0.02 in that year. The percentages of students in Ireland who reported that they 'very often' or 'regularly' visited web sites about science topics increased significantly by 5.7% since 2006. There was a similar increase (5.5%) on average across OECD countries. The increased access to websites for science information is mirrored by a significant 2.3% reduction in Ireland (and a reduction of 5.1% on average across OECD countries) in the proportion who read science articles in magazines or newspapers.

Table 8.26 summarises students' career expectations at age 30 in 2006 and 2015. The table shows that the percentages of students expecting to be in various career groups linked to science at age 30 (see Chapter 7 for explanations) are broadly similar in 2006 and 2015, and are similar to the corresponding OECD averages. Small but significant increases (about 2%) were recorded for health professionals and information and communication technology professionals in Ireland.

Table 8.25. Mean scores and difference scores on index of engagement in science-related activities and frequency of engagement (very often or regularly) in Ireland and on average across OECD countries, 2006-2015

	2006				2015				Difference 2015-2006			
	IRL		OECD		IRL		OECD		IRL		OECD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SED	Mean	SED
Index of Engagement in Science-related Activities	-0.43	(0.02)	0.05	(0.00)	-0.37	(0.02)	-0.02	(0.00)	**0.06**	(0.03)	**-0.06**	(0.00)
Percent of Students who:	%	SE	%	SE	%	SE	%	SE	% diff	SE	% diff	SE
Watch TV programmes about science	17.6	(0.6)	22.2	(0.1)	16.8	(0.5)	23.0	(0.1)	-0.8	(0.8)	**0.8**	(0.2)
Borrow or buy books on science topics	5.0	(0.3)	8.7	(0.1)	6.3	(0.3)	11.1	(0.1)	**1.3**	(0.5)	**2.4**	(0.1)
Visit websites about science topics	8.7	(0.5)	13.6	(0.1)	14.4	(0.5)	19.1	(0.1)	**5.7**	(0.7)	**5.5**	(0.1)
Read science magazines or science articles in newspapers	10.8	(0.5)	20.9	(0.1)	8.5	(0.4)	15.8	(0.1)	**-2.3**	(0.6)	**-5.1**	(0.2)
Attend a science club	1.1	(0.2)	4.7	(0.1)	1.6	(0.2)	8.3	(0.1)	0.4	(0.2)	**3.6**	(0.1)

Significant differences are in bold.

Table 8.26. Percentage of students with various career expectations by age 30 in Ireland and on average across OECD countries, 2006-2015

	2006				2015				Difference 2015-2006			
	IRL		OECD		IRL		OECD		IRL		OECD	
Career	%	SE	%	SE	%	SE	%	SE	%	SED	%	SED
Science and engineering professionals	9.8	(0.5)	8.1	(0.1)	8.8	(0.4)	8.8	(0.1)	-1.1	(0.7)	**0.7**	(0.1)
Health professionals	11.9	(0.5)	8.7	(0.1)	13.8	(0.6)	11.6	(0.1)	**1.9**	(0.8)	**3.0**	(0.1)
Information and communication technology professionals	1.4	(0.2)	2.4	(0.0)	3.4	(0.3)	2.6	(0.0)	**2.0**	(0.3)	**0.2**	(0.1)
Science-related technicians and associated professionals	0.6	(0.1)	1.5	(0.0)	1.3	(0.2)	1.5	(0.0)	**0.7**	(0.2)	0.0	(0.0)
Students who expect to work in other occupations at age 30	59.2	(0.9)	56.3	(0.2)	59.7	(0.8)	56.7	(0.1)	0.5	(1.2)	0.4	(0.2)

Significant differences are in bold.

Table 8.27. Percentage of students who expect to work in science-related occupations at age 30, by gender and performance in science in 2006 and 2015, in Ireland and on average across OECD countries

	2006				2015				Difference 2015-2006			
	IRL		OECD		IRL		OECD		IRL		OECD	
	%	SE	%	SE	%	SE	%	SE	%	SED	%	SED
All students	23.8	(0.8)	20.6	(0.1)	27.3	(0.7)	24.5	(0.1)	**3.5**	(1.1)	**3.9**	(0.2)
By gender												
Male	24.8	(1.2)	21.7	(0.2)	28.0	(0.9)	25.0	(0.2)	**3.1**	(1.5)	**3.3**	(0.2)
Female	22.7	(0.9)	19.5	(0.2)	26.6	(1.0)	23.9	(0.2)	**3.8**	(1.3)	**4.4**	(0.2)
By performance level												
Low performers[41]	10.0	(1.2)	9.4	(0.2)	14.1	(1.5)	13.3	(0.2)	**4.1**	(1.9)	**3.9**	(0.3)
Moderate performers	20.3	(0.9)	18.8	(0.2)	25.0	(0.9)	23.1	(0.2)	**4.7**	(1.3)	**4.3**	(0.2)
Strong Performers	32.9	(1.6)	30.5	(0.3)	37.4	(1.8)	34.1	(0.4)	4.5	(2.3)	**3.5**	(0.5)
Top performers	45.5	(2.7)	40.3	(0.7)	45.7	(3.3)	41.7	(0.6)	0.2	(4.3)	**2.9**	(0.8)

Significant differences are in bold. SE = standard error; SED = standard error of the difference.

[41] Low performers – students performing below Level 2 in science; Moderate performers – students performing at Levels 2-3;, Strong performers – students performing at Level 4; Top performers – students performing at Level 5 or above.

Table 8.27 provides additional information on trends in science-related careers for male and female students, and for students with varying levels of proficiency in science, in the period 2006-2015. There are small but significant increases in Ireland in the proportions of male students (24.8% to 28.0%) and female students (22.7% to 26.6%) who aspire to science-related careers. The increases in Ireland are matched by similarly-sized increases on average across OECD countries.

Table 8.27 also shows a relationship between proficiency in science, as measured by PISA, and science-related career aspirations. Hence, there were small but significant increases (4.1%) in Ireland in the percentage of low-achievers in science in 2015 (those performing below Proficiency Level 2) who aspired to holding a science-related occupation by age 30, compared with 2006. There was also a significant increase in the proportion of moderate performers (those performing at Proficiency Levels 2-3), from 20.3% to 25.0%, who aspired to hold a science-related career by age 30. Although 4.5% more strong performers in science (Proficiency Level 4) aspired to science-related careers in 2015, compared with 2006, the difference is not statistically significant. There was a negligible change (0.2%) among top performers. On average across OECD countries, there were small but significant increases in science-related career expectations at all five levels of performance, with the smallest increase among top performers (2.9%).

8.6. Trends in Item Percent Correct Scores

This section examines trends in performance on clusters of science items in Ireland, on average across OECD countries, in Korea, and in a number of countries that performed at about the same level as Ireland on PISA 2012 science (Austria, Canada, Germany and the Netherlands). As noted in Chapter 1, the PISA 2015 science test item pool comprised the following components:

- 53 trend items that had been administered in 2006, 2009, 2012 and 2015
- 80 trend items administered in 2006 and 2015, including the 53 trend items administered in 2009 and 2015
- 75 new non-interactive science items administered for the first time in PISA 2015
- 24 interactive items administered for the first time in PISA 2015.

The data in Table 8.28 represent weighted percent correct scores. Students in Ireland achieved a mean score of 55.1% correct on the 53 trend items in 2006. This increased to 57.2% in 2012 (in line with Ireland's higher overall mean score), and fell back to 54.9% correct in 2015. In the period 2006-2015, the mean percent score of students in Ireland on these items dropped by just 0.2%. This contrasts with large drops in Australia (-5.2%), Canada (-3.2%) and Korea (-4.1%). In the period 2012-2015 (i.e., in the transition from paper-based to computer-based testing), Ireland's mean percent correct score fell by -2.3%. However, there were relatively larger declines in Australia (-4.7%), Canada (-2.7%), Korea (-7.1%), Germany (-4.7%), the Netherlands (-4.2%) and on average across OECD countries (-4.6%). Hence, the decline in Ireland between 2012 and 2015 on the 53 long-term PISA science trend items was relatively small compared with other comparison countries and with the average decline across OECD countries.

Ireland also performed reasonably well on the 80 trend items administered in 2006 and 2015 (these included the 53 long-term trend items). There was a drop of just 0.5% between these years, compared with larger drops in Australia (-5.2), Canada (-3.4%), Korea (-4.4%), Germany (-3.0%) and the Netherlands (-5.1%). Hence, unlike Ireland, Australia, Canada and the Netherlands were more disadvantaged by the addition of 27 items from PISA 2006 to the 2015 item pool (that is, items from 2006 that had not been administered in either 2009 or 2012, but brought back into service in 2015).

Unlike trend items, the 99 new items introduced in 2015 were only ever administered on computer. These were divided into 75 non-interactive items (which, arguably, could have been administered on paper or computer – they tended not to capitalise on the affordances of technology), and 24 interactive items (some of which capitalised on the affordances of technology – see Chapter 3). Ireland did less well on the 99 new items as a group (48.9% correct), compared with, for example, Australia (50.7% correct), Canada (54.6% correct), and the Netherlands (50.8% correct). On average across OECD countries, however, the percent correct score on these items (46.6%) was marginally lower than in Ireland (48.9%). The last row in Table 8.29 illustrates this in clearest terms. Compared with its performance on the 53 trend items in 2015, Ireland had a mean score on the new science items that was 6.0% lower. None of the comparison countries had a difference that was this large; differences in Australia (-2.2%), Canada (-1.6%), Korea (-2.1%), Germany (-3.5%) and the Netherlands (-3.1%) were all lower. On average across OECD countries, the difference (-2.7%) was also smaller than in Ireland.

Table 8.28. Percent correct scores on selected science items, Ireland, OECD average and selected comparison countries, 2006-2015

	Ireland	Australia	Canada	Korea	Germany	Netherlands	OECD
Percent Correct for 53 trend items							
2006	55.1	58.1	59.5	57.8	57.1	58.7	53.3
2009	54.5	59.0	59.2	60.7	58.7	58.0	53.8
2012	57.2	57.6	58.9	60.8	59.3	58.1	54.0
2015	54.9	52.9	56.2	53.7	54.6	53.9	49.3
Diff (2015-2006)	-0.2	-5.2	-3.2	-4.1	-2.5	-4.8	-4.0
Diff (2015-2012)	-2.3	-4.7	-2.7	-7.1	-4.7	-4.2	-4.6
Percent correct for 80 trend items							
	Ireland	Australia	Canada	Korea	Germany	Netherlands	OECD
2006	54.2	58.2	59.9	57.5	57.0	58.3	53.1
2015	53.7	53.0	56.5	53.1	54.1	53.2	48.9
Diff (2015-2006)	-0.5	-5.2	-3.4	-4.4	-3.0	-5.1	-4.2
Percent correct for new items vs trend items in 2015							
	Ireland	Australia	Canada	Korea	Germany	Netherlands	OECD
99 new	48.9	50.7	54.6	51.6	51.1	50.8	46.6
75 non-interactive	51.9	53.1	56.6	54.1	53.4	53.3	48.8
24 interactive	39.5	43.1	48.3	43.9	43.9	43.2	39.9
80 trend	53.7	53.0	56.5	53.1	54.1	53.2	48.9
53 trend	54.9	52.9	56.2	53.7	54.6	53.9	49.3
Diff (New v 80)	-4.8	-2.3	-1.9	-1.5	-3.0	-2.3	-2.3
Diff (new v 53)	-6.0	-2.2	-1.6	-2.1	-3.5	-3.1	-2.7

2015 data weighted on the August 2016 release, previous years from OECD compendia. Trend data do not include five items: Four administered in 2003 and 2015 only (S252Q01-03, S327Q01) and one item administered in 2006 and 2015, for which item level data was not available for 2006).

The data in Table 8.28 also allow for a comparison between how selected countries performed on the interactive and non-interactive new computer-based items. On average across OECD countries, the average percent correct score on non-interactive items was 48.8%, while on interactive items it was

39.9%. Hence, on average across OECD countries, the new interactive items were considerably more difficult than either the new non-interactive items, or the trend items (48.9% on the 80 trend items). Students in Ireland also found the interactive items difficult. The mean percent correct score on these items (39.5%) was about the same as the OECD average (39.9%), and lower than in any of the comparison countries. While Ireland's performance on the non-interactive new items (51.9% correct) was above the corresponding OECD average (48.8%), it was lower than in any of the comparison countries.

As noted earlier in this chapter, Ireland's mean score on PISA 2015 was 5.8 score points lower than in 2006. The data on item difficulty indicate a difference of just 0.5% on the 80 PISA trend items administered in both 2006 and 2015. This is likely to have contributed to the non-significant decline of 5.8 score points between 2006 and 2015, along with relatively low performance on the 99 new PISA items, though Ireland did achieve a mean score (48.9%) that was higher than the OECD average (46.6%) on those items.

The decline in Ireland on overall science between 2012 and 2015 was a significant 19.4 score points. This reflects the 2.3% drop in performance on the 53 trend items between 2012 and 2015, as well as relatively low performance on new trend items in 2015. Australia, which performed at the same level as Ireland in 2012 (mean science scores of 522.0 and 521.5 respectively) achieved a significantly higher mean score than Ireland in 2015 (510.0 compared to 502.6 in Ireland). In 2015, Australia had a lower mean percent correct score (52.9%) on the 53 trend items administered in 2012 and 2015, compared with Ireland (54.9%), and its mean percent correct score on these items had dropped by 4.7%, compared to 2.3% in Ireland. However, Australia (50.7%) fared better than Ireland (48.7%) on the new science items administered in 2015 and this may well have cancelled out Australia's poorer performance on the proportionally smaller number of trend items. The Netherlands also had a lower mean percent correct score in 2015 on the 53 trend items administered in 2012 and 2015 than Ireland (53.9% vs. 54.9% respectively), reflecting a drop of 4.2% since 2012, compared to 2.3% in Ireland. However, the Netherlands outperformed Ireland on the new science items in 2015 (50.8% correct, vs. 48.9% in Ireland), and this may have contributed to the higher (albeit not statistically significant) overall score in the Netherlands in 2015, compared with Ireland. These comparisons suggest that Ireland was penalised to a greater degree than might have been expected for its weaker performance on new science items in PISA 2015.

Table 8.29 provides average percent correct scores on reading literacy and mathematics between 2012 and 2015 in Ireland, in five comparison countries, and on average across OECD countries. On 43 reading trend items administered in 2009, 2012 and 2015, students in Ireland showed an improvement of 1.5% between 2009 and 2015, and a drop of 2.1% between 2012 and 2015. The inclusion of additional reading items (from the 2009 pool) on the 2015 reading literacy test may have benefited Ireland to a greater extent that other countries, given our low performance on those items in 2009.

Table 8.29. Mathematics and reading item response statistics for Ireland, selected countries and across OECD countries on average, 2009-2015

	Percent Correct						
	Ireland	Australia	Canada	Korea	Germany	Netherlands	OECD
Reading – 43 trend items administered in 2009, 2012 and 2015							
2009	61.7	63.5	65.9	67.6	63.2	63.8	60.2
2012	65.3	63.1	65.8	67.8	64.0	63.9	60.6
2015	63.2	59.3	63.6	61.6	61.6	62.2	57.1
Diff (2015-2009)	1.5	-4.2	-2.3	-5.9	-1.7	-1.6	-3.1
Diff (2015-2012)	-2.1	-3.8	-2.2	-6.2	-2.4	-1.7	-3.4
Reading – 85 trend items administered in 2009 and 2015							
2009	61.7	64.0	66.4	69.5	63.1	63.3	60.8
2015	63.5	59.8	64.4	64.5	62.6	62.5	58.0
Diff (2015-2009)	1.8	-4.2	-2.0	-4.9	-0.6	-0.8	-2.8
Mathematics for 69 trend items in 2012 and 2015							
2012	48.6	49.7	52.4	58.8	51.6	53.3	47.6
2015	47.5	46.3	50.4	52.7	48.8	49.1	43.3
Diff (2015-2012)	-1.1	-3.3	-1.9	-6.1	-2.8	-4.2	-4.3

Items R219Q01, R219Q01E and R432Q06 are not included as no data on performance on these items are available for 2009

Ireland's mean percent correct score on mathematics dropped by 1.1% on 69 mathematics trend items between 2012 and 2015. This decline was smaller than in any of the comparison countries, or an average across OECD countries (Table 8.30). Paradoxically, there was a non-significant increase in Ireland's mean scale score in mathematics between these years (from 501.5 to 503.7), though this may also reflect other factors, including, for example, the replacement of international item parameters by national parameters on items on which there were significant country-by-mode interactions.

8.7. Effects of Changes to Scaling Procedures

As noted in Chapter 1, the Educational Testing Service made some significant changes to the procedures used for scaling PISA data in 2015, compared with earlier cycles. These included a scaling model that could accommodate 2-parameter and Rasch item functions. There were also changes to the treatment of misfitting items identified though differential item functioning (these were assigned unique country parameters rather than being dropped), and with the treatment of not-reached items at the end of each hour of testing (these were treated as not administered rather than incorrect).

In response to concerns raised by countries, the OECD released data on the effects of applying the 2015 approach to scaling the data to earlier cycles of PISA. Table 8.30 gives the mean score differences for Ireland and the other comparison countries considered in this chapter for 2015 and the previous cycle in which each domain had major domain status. The 'published change' column under each domain denotes the difference between the scaled value in 2015 and the published mean score for the earlier cycle (i.e., the actual differences reported for each domain earlier in this chapter), and the 'change with rescaling' column indicates what the difference would have been if the earlier cycle had been scaled in the same way as the 2015 data.[42] Thus, for science in Ireland between 2006 and 2015,

[42] It should be noted that certain features the PISA design in earlier cycles, such as the (limited) number of link items used to measure change, could not be modified during rescaling.

there was a non-significant drop of 5.8 score points. However, if the 2015 scaling procedures had been in place in 2006, the drop in Ireland between 2006 and 2015 would have been just one score point. Similarly, while performance on reading literacy increased by 25.2 score points between 2009 and 2015, it would have increased by 27 score points if the 2015 approach to scaling had been in place in 2009. The increase in performance in mathematics in Ireland between 2012 and 2015 (2.2 points) would have been 6.0 points if the new scaling procedures had been in place in 2012.

Table 8.30. Differences arising from application of new scoring method (rescaling) to earlier cycles of PISA (major domain to major domain), Ireland, comparison countries and OECD average

	Science (2006 – 2015)		Reading Literacy (2009-2015)		Mathematics (2012-2015)	
	Change with Rescaling	Published Change	Change with Rescaling	Published Change	Change with Rescaling	Published Change
Ireland	-1.0	-5.8	27.0	25.2	6.0	2.2
Australia	-14.0	-16.9	-12.0	-12.0	-8.0	-10.3
Canada	-4.0	-6.8	2.0	2.4	-2.0	-2.4
Korea	-10.0	-6.3	-9.0	-21.8	-24.0	-29.7
Germany	-8.0	-6.5	11.0	11.8	-5.0	-7.6
Netherlands	-19.0	-16.3	4.0	-5.4	-10.0	-10.7
OECD Average	-3.4	-3.8	-0.1	-1.1	-2.5	-3.7

Source: OECD (2016b), Annex Table AT2, AT3 and AT4 (web-based tables).

For most countries, score differences arising from a rescaling of older data are small, and within the error margins of published difference scores. However, a few countries have been affected by the change to a greater extent than most. Performance in Korea, for example, dropped by 21.8 points on reading literacy between 2009 and 2015. If the 2015 scaling procedures had been used back in 2009, the drop would have been 9 score points.

It is unclear what specific aspects of rescaling have contributed to observed differences in Ireland and elsewhere.

8.8. Summary and Conclusion

This chapter provided an overview of trends in performance in science (the major assessment domain in PISA 2015), reading literacy (a minor domain) and mathematics (also a minor domain) across recent cycles of PISA, as well as trends in a number of non-cognitive variables such as attitudes towards science and career expectations at age 30. Consideration was also given to the performance of students in Ireland and in selected countries on clusters of PISA items, including trend items (items administered on paper in earlier PISA cycles, and administered on computer for the first time in 2015), and new items (items used in computer-based assessment for the first time in 2015).

Although PISA advises that the safest comparisons can be drawn when a major domain is compared with major domain (such as science in 2015 with science in 2006), comparisons are also drawn from minor domain back to major domain (such as reading between 2009 and 2015, and mathematics between 2012 and 2015), and, most problematically, from major domain back to minor domain (such as science from 2015 to 2012), as the most recent minor domain does not reflect changes that may have been made to assessment framework.

In considering trends in performance, it should be noted that PISA 2015 differed in substantive ways from earlier cycles. The OECD worked with a new team of contractors who introduced new scaling methodologies, new approaches to dealing with not-reached items, and new strategies for dealing with items that demonstrated significant country-by-item interactions. In addition, PISA moved from a paper-based to a computer-based assessment in most participating countries. This entailed transferring PISA trend items from paper to computer format for all domains, and introducing new items in the major domain (science) that sought to capitalise on the affordances offered by computer-based technology, including new interactive items.

Across cycles of PISA, Ireland's mean science performance has changed in ways that are different to reading literacy and mathematics. In 2009, for example, students in Ireland achieved a mean science score (508.0) that was not significantly different from 2006 (508.3), even though average performance on reading literacy and mathematics dropped substantially between these years. Ireland's performance in science in 2009 may have hidden an actual improvement, if performance in science was also affected by factors that contributed to the declines in reading literacy and mathematics such as demographic changes and low engagement among participating students. It is perhaps not surprising then that performance increased substantially between 2009 and 2012, when the mean score increased to 522.0 (in tandem with a similarly-sized increase in reading literacy, and a smaller increase in mathematics). In 2015, performance on science dropped to 502.6 (on the same scale established in PISA 2003, and employed in subsequent cycles).

The drop of 5.8 points in science in Ireland between 2006 and 2015 (the OECD's preferred comparison window) is not statistically significant. Other countries experienced greater declines than Ireland including Finland (-32.7), New Zealand (-17.1), and Austria (-15.8). However, unlike Ireland, these countries also experienced declines in performance in 2012, and this may explain, at least in part, why their mean scores did not drop to the same extent as in Ireland between 2012 and 2015.

Besides Ireland, a number of other countries experienced a significant drop in science performance between 2012 and 2015. Hong Kong (China) experienced a drop of 31.7 score points. Like Ireland, Poland and Korea experienced significant drops in the order of 20 score points. Countries with smaller (but still statistically significant) declines included the Czech Republic (-15.5), Germany (-15.0), Finland (-14.8), the Netherlands (-13.5), Latvia (-12.0), and Australia (-10.7). On average across OECD countries, there was a significant drop of 8.0 score points. Only Portugal showed a significant improvement. It is notable that the countries with the largest declines in science performance between 2012 and 2015 were among the highest performers in 2012 and, in the case of countries like Australia, Finland and Korea, were also among the highest performers in earlier PISA cycles.

The analysis of trends by proficiency level and by gender point to where the greatest declines in science performance occurred between 2012 and 2015, as well as between 2006 and 2015. In Ireland, the percentage of students performing below Level 2 ('low' performers in science) dropped significantly from 15.5% in 2006 to 11.1% in 2012, and increased to 15.3% in 2015). Hence, there were similar proportions of low achievers in Ireland in 2006 and 2015. In contrast, the proportion of students in Ireland performing at or above Proficiency Level 5 ('high' achievers) increased from 9.4% in 2006 to 10.7% in 2012, before dropping to 7.1% in 2015 (and not significantly different from the OECD average of 7.7%). There are significantly fewer higher achievers in science in Ireland in 2015, compared with both 2006 and 2012.

Another group that fell behind in PISA 2015 science in Ireland are female students. In 2006, female students had a mean score that was higher than male students by a non-significant 0.4 score points. By 2015, there was a significant 10.5 points difference in favour of male students. The corresponding OECD average in 2015 is 3.5 score points in favour of males. An analysis of science performance by proficiency level across genders indicates a greater increase in the proportion of lower-performing females compared with males between 2012 and 2015, and a somewhat greater decline in the proportion of high-performing females compared with males (a significant decline of 4.7% for females, and 2.7% for males). More positively, the standard deviation in science in Ireland, and well as the inter-decile range (the gap between the 10th and 90th percentiles) declined across successive PISA cycles, pointing to greater equity in science outcomes. While most improvement was made on these measures of variance between 2009 and 2012, they are well ahead of 2006 levels in 2015, and improvements made in 2012 have not dissipated.

It is unclear to what extent the transition to computer-based testing contributed to the large drop in mean performance in science in Ireland between 2012 and 2015. The analysis of item-level data presented in this chapter suggests that, compared with a set of countries that performed at the same level on PISA science as Ireland did in 2012, students in Ireland performed disproportionately poorly on new science items (i.e., those items specifically developed for computer-based testing in 2015), and especially on items described as 'interactive'. The persistently low levels of engagement with ICT for school-related tasks in school and for homework by students in Ireland may explain, in part, why students in Ireland struggled with the new PISA science items, including, in particular, those that required them run simulations, while manipulating a number of variables at the same time. The stronger perceived ICT competence among male students, and their greater involvement in social discussions about ICT (see Chapter 6) may also have contributed to the greater gender difference in science in Ireland in 2015, compared with earlier PISA cycles.

An analysis of the distributions of grades on Junior Certificate science between 2006 and 2015 (including 2012-2015) described in this chapter does not point to a decline in science performance, at least among students in Third year. While there has been in increase in proportion of Third year students nationally taking Junior Certificate science from 86.2% in 2006 to 91.2% in 2015 (with a greater increase among females that males), and the percentage of science candidates taking the Higher level paper has increased from 67.3% to 78.6% between these years, there have only been small changes in the distribution of grades, with, for example, a slight increase in the percentages of A-C grades at Higher level awarded in 2015, compared with 2012.

Reading literacy was a minor assessment domain in PISA 2015. Ireland's mean score increased substantially between 2009 and 2012, returning to the level achieved between 2000 and 2006. Hence, the large increase in mean performance between 2009 and 2015 described in the OECD (2016b) report on PISA 2015 had, to an extent, already been factored into Ireland's score in 2012. Ireland's mean score was marginally, but not significantly, lower (by 2.4 score points) in 2015, compared with 2012, when reading literacy was also a minor domain. It is notable that just five countries experienced significant declines in reading performance between 2012 and 2015, including Japan (-22.1), Korea (-18.4), and Switzerland (-16.8), while three had significant increases (Slovenia, 23.9; the Russian Federation, 35.2; and Sweden, 16.8). It is unclear if these changes can be attributed to the transition to computer-based testing, the doubling of the number of trend items relative to earlier minor-to-minor cycles, or to other reasons (for example, Sweden's performance had declined across a number of previous cycles and might have been expected to recover at some stage). It may be that, in Ireland, recent initiatives to improve literacy (see Chapter 2) acted as a buffer, such that, without them, performance could well have declined in the context of the transition to computer-based testing (similar to science in Ireland in 2009, when the introduction of a new syllabus in 2003 may have prevented Ireland's mean score from falling in the same way as reading literacy and mathematics fell in that year). It may also be the case that the addition of over 40 reading items previously administered in PISA 2009 to the PISA 2015 item pool favoured Ireland in that the improvement in performance on those items may have been factored into Ireland's performance in 2015 for the first time.

While female students in Ireland and on average across OECD countries performed significantly better than males on PISA 2015 reading, the gender gap in Ireland was smaller in 2015 (12.0 score points) than in 2012 (28.5) or in earlier cycles. Furthermore, the gender gap in Ireland is now well below the average across OECD countries, which was 27.1 score points in 2015, down from 39.3 in 2012. Hence, while the gender narrowed both in Ireland and on average across OECD countries in the course of transitioning to computer-based testing (albeit with the same texts that appeared on paper in earlier cycles). We know from PISA 2009 and PISA 2012, when digital reading was assessed as well as print reading, that gender differences can be smaller on digital texts than on print texts (see Chapters 2 and 3). What is potentially problematic is the drop of 3.7% (albeit not significant) in the proportion of female students performing at or above Proficiency Level 5 in Ireland between 2012 and 2015.

PISA 2015 was the first cycle in which all participating students in Ireland had studied under the Project Maths syllabus. However, it is difficult to gauge the impact of Project Maths on performance, given the other changes to PISA in 2015, including the transition to a computer-based platform. Mathematics was a minor assessment domain in 2015.

Ireland's mean score on PISA mathematics was 502.8 in 2003, 501.5 in 2006 and 487.1 in 2009. Performance returned to the same level as in 2006 (501.5) again in 2012, when mathematics was a major assessment domain, and improved slightly to 503.7 in 2015. Ireland's mean score was above the OECD average in both 2012 and 2015. Ireland's relatively stable performance between 2012 and 2015 is remarkable in that 8 of the top 30 highest-performing countries in 2012 experienced declines in 2015, including Korea (-29.7), Hong Kong (China) (-13.3), Poland (-13.0), the Netherlands (-10.7) and Australia (-10.3), and five experienced significant increases, including Sweden (+15.7), Norway (+12.4) and Denmark (+11.1). As with reading literacy, it is unclear if the transition to computer-based assessment is responsible for these changes, and, if so, why. It may be that, in Ireland, changes arising from Project Maths, with its focus on real-life problem solving and higher-level thinking, enabled students to maintain and even improve a little on their performance in earlier PISA cycles (2009 notwithstanding). One of the explanations for Ireland's stable performance on reading literacy in 2015 – the inclusion of over 40 new trend items administered only in 2009 and 2015, on top of the trend items administered in 2012 and 2015 – can be ruled out in the case mathematics, since all trend items administered in that year had also been administered in 2012. Hence, if there was a potential decline built into PISA 2015 mathematics due to the transition to computer, gains brought about by Project Maths could have cancelled this out.

In 2015 in Ireland, there was a gap of 16.1 score points in favour of male students on mathematics, up from 15.3 points in 2012, and well above the 2015 OECD average of 7.7 (which fell back from 10.3 in 2012). Indeed, in 2015, in contrast with the situation in reading, Ireland had one of the largest gender gaps in mathematics among OECD countries. Again, it is a matter of concern that just 6.5% of female students in Ireland performed at or above Level 5 on mathematics, down from 8.5% in 2012, and well below the OECD average of 9.0% in 2015, which itself dropped from 10.8% in 2012.

There was a drop of 4.8 points in Ireland's standard deviation in mathematics between 2012 and 2015, and it is now 79.8 points – well below the OECD average of 98.4. However, lower performance among higher-achieving female students could have contributed to this.

As noted in Chapter 3, the OECD and their contractors conducted an extensive mode study in 2014, in preparation for the PISA 2015 assessment, and concluded that it was feasible to estimate trends in performance despite the transition from paper to computer, in part based on a correlation of .94 between item parameters arising from the paper-based and computer-based tests administered in the mode study. This study was based on pooled country-level data, as there were insufficient numbers of students in participating countries to draw firm conclusions about within-country mode effects. It seems clear that the combination of adding new computer-based science items to the pool of paper-based items transferred to computer may not have worked out as well as was hoped, and that it may take one or more cycles before the new, computer-based science assessment stabilises.

In general, the characteristics of the PISA 2015 sample in Ireland were found to be similar to those of earlier PISA cycles. However, there was a notable increase in the proportion of students described as immigrant speakers of English or Irish (up from 3.6% in 2006 to 7.3% in 2015) and immigrant speakers of other languages (up from 1.7% to 7.1% between the same years), though the latter group may have included some exchange students from other EU countries who were studying in Ireland for part of the 2014-15 school year. The proportion of students in Transition year also increased, from 21.2% in 2006 to 26.7% in 2015, with a parallel increase in the proportion in Fifth year (from 17.5% to 10.9%). The proportions studying science in the Junior Certificate examination increased from 82.6% in 2006 to 91.2% in 2015. Further, among those taking science, the proportion taking the Higher-level science paper increased from 67.3% in 2006 to 78.6% in 2015. There is no clear evidence that any of these changes contributed to the substantive difference in science performance on PISA between 2012 and 2015.

It is encouraging that students in Ireland report a large and significant increase in their Enjoyment of Science between 2006 and 2015 and that Ireland's mean score on this index is now significantly above the OECD average. It is also noteworthy that Instrumental Motivation to learn science has increased significantly, perhaps because students are more aware of the importance of science in the context of their future careers. Although there has been an increase in Ireland's mean score on the PISA index of Science Activities, it still lags behind the corresponding OECD average score, and students in Ireland continue to report low involvement in activities such as visiting web sites about science topics, reading science magazines, and attending science clubs. There have been some small increases between 2006 and 2015 in the proportions of students in Ireland expecting to be in science-related occupations by age 30, and roughly equivalent proportions of male and female students (23-25%) expect to work in these occupations. Surprisingly, perhaps, just 3.4% of students in 2015 expect to work as information and communication technology professionals by age 30.

Chapter 9: Summary, Conclusions and a Look Ahead

This chapter is divided into three main parts – a summary of the key findings of PISA 2015, and a set of conclusions based on the findings, and a look at new developments planned for PISA 2018.

9.1. Summary

The Programme for International Student Assessment (PISA) is a project of the Organisation for Economic Cooperation and Development (OECD), of which Ireland is a member. PISA, which has taken place every three years since 2000, assesses the preparedness of 15-year-olds to meet the challenges they may encounter in their future lives, including their future education (OECD, 2016a). In 2015, over 500,000 15-year-olds in 72 countries/economies took part in PISA,[43] including all 35 OECD countries. Science was the major assessment domain in 2015, with reading literacy and mathematics designated as minor domains. In Ireland, PISA is implemented by the Educational Research Centre, on behalf of the Department of Education and Skills.

9.1.1. Changes to PISA in 2015

In earlier assessment cycles, the main PISA tests were administered on paper in all participating countries, while some computer-based testing was conducted on an experimental basis in subsets of countries. In 2015, most participating countries, including all 35 OECD-member countries, administered the tests (and questionnaires) on computer. Drawing on data from the PISA 2015 Field Trial (administered in 2014), the OECD and its contractors investigated whether performance on computer-based tests in 2015 could be linked back to earlier paper-based scales, thereby maintaining trend lines. The mode-effect study, which used pooled data across countries, concluded that a link back to earlier paper-based cycles could be maintained (OECD, 2016b).

In addition to the change in assessment mode in PISA 2015, significant changes were introduced into the test design and scaling of student performance. Changes to the test design involved increases in the proportions of items assessed in the minor domains, and in the proportions of students who completed one hour of testing on each of the minor domains, compared with earlier cycles. These changes were intended to improve construct coverage, as well as provide a more coherent experience for test takers. There were also changes in scaling related to the size of the calibration sample, the scaling model, the treatment of items that function differentially across countries, and the treatment of not-reached items during scoring. While many of these changes may well improve the stability and accuracy of scores in future PISA cycles, they complicate the interpretation of scores in PISA 2015.

9.1.2. Implementation of PISA 2015 in Ireland

PISA 2015 was implemented in Ireland in March 2015. A representative sample of 169 schools was selected to take part, and, of these, 167 participated, giving a weighted response rate of 99.3%. Within each school, up to 42 students who met the age-based criterion (born in 1999) were selected to take part. In all, 5,741 students completed PISA, yielding a weighted student response rate of 88.6%, after ineligible students and students with special needs had been accounted for. The students were distributed over four grade levels – Second year (1.9%), Third year (60.5%), Transition

[43] Of these, 70 had gathered achievement data that could be compared across countries.

year (26.7%), and Fifth year (10.9%). Across grade levels, 48.7% of students were females and 51.3% were males.

PISA was administered in schools by members of the inspectorate of the Department of Education and Skills and by staff of the Educational Research Centre. Students completed the assessment on laptop computers, brought to schools and set up by technical support persons. A typical PISA assessment session took over 3.5 hours, and includes a general introduction to the test on computer, two one-hour slots allocated to the computer-based tests of science, reading literacy and mathematics in various combinations, and about an hour to computer-based student questionnaires. Principal teachers and science co-ordinators in participating schools, and parents of participating students also completed questionnaires. Tests and questionnaire items were scaled by the OECD's contractors, and the weights to be applied to student responses were computed by them.

9.1.3. Performance on science in PISA 2015

Ireland's mean score on the overall science literacy scale (502.6) in PISA 2015 is significantly higher than the OECD average (493.2), and is also significantly higher than the mean scores of 45 PISA-participating countries/economies. Ireland's science performance ranks 13th among all OECD countries, and 19th among the 70 PISA-participating countries and economies with valid data. With a 95% confidence interval applied, Ireland's true rank in science lies between 11th and 18th in the OECD, and between 17th and 24th among all participating countries and economies. The highest performing country/economy overall in science is Singapore, which, with a mean score of 555.6, significantly outperforms all other countries/economies. The next highest performers are Japan (538.4), Estonia (534.2), Chinese-Taipei (532.3) and Finland (530.7). Performance on science in Ireland does not differ significantly from the performance of the United Kingdom, Germany, the Netherlands, Switzerland, Belgium, Denmark, Poland, Portugal, Norway, the United States. Mean performance in Northern Ireland (500.0), a region of the United Kingdom in PISA, is not significantly different from that of Ireland.

The range in science achievement in Ireland (the difference between the 95th and 5th percentiles) is 291.9 points, which is significantly narrower than the average of 308.7 points across OECD countries.

Ireland has fewer lower-performing students – those scoring below Proficiency Level 2 (15.3%) – compared with the OECD average of 21.2%. Countries with lower proportions of students than Ireland below Level 2 include Estonia (8.8%), Japan (9.6%), Singapore (9.6%), Canada (11.1%) and Finland (11.5%). The proportion of high performers – those scoring at Proficiency Level 5 or above – is about the same in Ireland (7.1%) as on average across OECD countries (7.7%). Countries with higher proportions of students than Ireland performing at these levels include Singapore (24.4%), Japan (15.3%), Finland (14.3%), Estonia (13.5%) and New Zealand (12.8%).

PISA 2015 assessed key competencies and knowledge for science literacy using eight overlapping subscales derived from the overall science scale. Ireland's mean score is significantly higher than the corresponding OECD average score on all three science competency subscales, with a relative strength on Explain Phenomena Scientifically, compared with Evaluate and Design Scientific Enquiry and Interpret Data and Evidence Scientifically. Ireland's mean scores on the Content Knowledge and Procedural and Epistemic Knowledge subscales are also higher than the corresponding OECD average scores. Students in Ireland also perform above the corresponding OECD averages on Physical Systems, Living Systems and Earth and Space Systems, with performance on Physical Systems identified as an area of relative strength.

Male students in Ireland significantly outperform female students by 10.5 score points on overall science, while on average across OECD countries, the difference in favour of male students is a significant 3.5 score points. Male students also perform significantly higher than females in the United States (by 6.8 points), Germany (by 10.5), and Japan (by 13.6). However, in Finland, female students score significantly higher on science than males by 19 score points. Similar percentages of male (15.7%) and female (14.9%) students in Ireland perform below Level 2 on overall science, but more males (9.0%) than females (5.0%) perform at or above Level 5. Similarly, on average across OECD countries, equivalent percentages of males (21.8%) and females (20.7%) perform below Level 2, while more males (8.9%) than females (6.5%) perform at or above Level 5. Hence, the OECD average proportions below Level 2 are higher than in Ireland for both males and females, while equivalent proportions of males and females in Ireland, compared with the corresponding OECD averages, perform at Level 5 or above.

Male students in Ireland significantly outperform their female counterparts on two of three science competencies (Explain Phenomena and Interpreting Data and Evidence), on one of two knowledge subscales (Content Knowledge), and on all three science knowledge systems (Physical Systems, Living Systems and Earth and Space Systems). The largest differences are on Explain Phenomena (17.2 points), Content Knowledge (17.5) and Physical Systems (11.1). Average differences across OECD countries also tend to favour male students, though to a lesser extent than in Ireland. On average across OECD countries, differences between competency, knowledge and systems subscales are small, though, as in Ireland, students perform marginally better on Physical Systems compared with other content systems.

9.1.4. Performance on reading literacy in PISA 2015

Students in Ireland achieved a mean score of 520.8 on reading literacy, which as significantly above the OECD average of 492.5. Ireland ranks 3rd of 35 OECD countries, and 5th among all participating countries/economies. Applying a 95% confidence interval, Ireland's 'true rank' is between 2nd and 6th among OECD countries, and between 4th and 8th among all participating countries. Only Singapore has a significantly higher mean score (535.1) than Ireland, while students in Ireland do not differ significantly in average performance from students in Hong-Kong China, Canada, Finland, Estonia, Korea or Japan. The mean reading score for Northern Ireland (497.0) is significantly below the mean score for Ireland, and is not significantly different from the OECD average.

The range in reading achievement in Ireland (the difference between the 95th and 5th percentiles) is 283.6 points, which is significantly narrower than on average across OECD countries (315.4).

Just 10.2% of students in Ireland perform at the lowest levels of reading proficiency (below Level 2) – about the same as in other high-performing countries including Estonia (10.6%), Canada (10.7%), Finland (11.1%) and Singapore (11.1%). On average across OECD countries, one-in-five students (20.1%) perform below Level 2. In Ireland, 10.7% of students perform at the highest proficiency levels in reading (Levels 5-6). This is about the same as in Germany (11.7%), Estonia (11.0%) and Sweden (10.0%), but lower than in Singapore (18.4%), Canada (14.0%) and Finland (13.7%). On average across OECD countries, 8.3% perform at Levels 5-6 in reading.

In Ireland, female students significantly outperform male students on reading literacy, by 12.0 score points. This compares favourably with the average gender difference of 26.9 points in favour of females across OECD countries. Countries with larger gender differences than Ireland include Finland (46.5), Korea (40.5), Sweden (39.2) and New Zealand (32.3). In Ireland, 8.0% of females and 12.3% of males perform below Proficiency Level 2, compared with 15.6% and 24.4% on average across OECD countries. Equal percentages of female and male students in Ireland (10.7%) perform at Levels 5-6, compared with OECD average percentages of 9.9% (females) and 6.8% (males).

9.1.5. Performance on mathematics in PISA 2015

In PISA 2015 mathematics, students in Ireland achieved a mean score of 503.7, and a ranking of 13th of 35 OECD countries, and 18th of 70 participating countries/economies. Applying a 95% confidence interval, Ireland's true rank lies between 10th and 14th among OECD countries, and between 15th and 19th among participating countries. Ireland's mean score is significantly above the OECD average score of 490.2. Fourteen countries/economies have significantly higher mean scores than Ireland including Singapore (which outperforms all other participating countries/economies), Hong-Kong China, Japan, Korea, Switzerland, Estonia and Canada. Countries that perform at about the same level as Ireland include Belgium, Germany, Poland, Norway and Austria. Countries with significantly lower mean scores than Ireland include New Zealand, Australia, the United Kingdom, Israel and the United States. Northern Ireland's mean score (493.8) is not significantly different from Ireland's mean score, or from the OECD average score.

The range in mathematics achievement in Ireland (the difference between the 95th and 5th percentiles) is 261.9 points, which is significantly smaller than the corresponding average of 293.3 across OECD countries, indicating a narrower range of performance in Ireland.

In Ireland, 15.0% of students perform at the lowest levels of mathematics proficiency (below Level 2), compared with an OECD average of 23.4%, indicating low performance. A number of countries including Singapore (7.6%), Japan (10.7%) and Estonia (11.2%) have fewer students than Ireland performing below Level 2. Just 9.8% of students in Ireland perform at the highest proficiency levels (Levels 5-6). The corresponding OECD average is marginally higher at 10.7%. A number of countries have significantly higher percentages of students performing at Levels 5-6, including Singapore (34.8%), Korea (20.9%) and Japan (20.3%).

The mean mathematics score of male students in Ireland (511.6) is significantly higher than the mean score of female students (495.4). Among a set of comparison countries, only Germany (16.6 points) has a difference in favour of male students that is similar to Ireland's (16.1). On average across OECD countries, male students significantly outperform female students by 7.9 score points. In Korea, female students have a mean score that is higher than that of males (by 7 score points), but the difference is not statistically significant. In Ireland, 14.1% of males and 15.8% of females perform below Proficiency Level 2 in mathematics, compared with 23.0% and 23.7% on average across OECD countries. Almost twice as many male students in Ireland perform at Proficiency Levels 5-6, compared with female students (12.9% vs. 6.5%). On average across OECD countries, more male students (12.9%) than female students (8.9%) perform at Levels 5-6.

9.1.6. Student- and school-level associations with achievement in PISA 2015

Data were gathered on a range of student and school background characteristics in PISA 2015 and their relationships to achievement were examined. At the student level, Economic, Social and Cultural Status (ESCS) is a strong predictor of achievement in all domains in Ireland and on average across OECD countries. In Ireland, students in Transition year have higher ESCS than students in all other grades assessed, and outperform students in the other grades on science, reading and mathematics. Students who attended pre-school (83.8%) also have higher ESCS. Pre-school attendance is positively associated with achievement across domains, while skipping school and being late for school are negatively associated with achievement. Students in Ireland have greater interest in Information and Communication Technology (ICT), and feel more competent and autonomous in its use, but they use ICT less often at school and at home for schoolwork compared to students on average across OECD countries. Almost three-in-five (57.2%) students in Ireland, and more females (60.5%) than males (54.0%), had never taken a computer-based test prior to PISA 2015.

At the school level, average school ESCS is significantly related to students' achievement in science, reading and mathematics. Differences in achievement also exist on the basis of school type, school fee-paying status and school participation in the Schools Support Programme (SSP) under DEIS. A better disciplinary climate in science class, as reported by students in Ireland, is associated with higher scores on science when school and student ESCS are taken into account, while greater perceived feedback from science teachers is associated with lower scores. Students in Ireland on average report similar frequencies of specific teaching practices in science class (adaptive instruction, inquiry-based instruction, and teacher-directed science instruction) as students across OECD countries on average. Greater frequencies of adaptive instruction and teacher-directed science instruction are associated with higher scores in science among students in Ireland. Some aspects of inquiry-based instruction (e.g., teachers clearly explaining the relevance of science concepts to students' lives) have positive associations with performance in science, while other aspects (e.g., students being allowed to design their own experiments) have negative associations. Compared to OECD countries on average, principals and parents in Ireland report greater efforts by schools to involve parents. Parents in Ireland report less participation in school-related activities than parents on average across OECD countries. Participation in some school-related activities, such as discussing a child's progress on the initiative of their teacher, is negatively associated with achievement, after accounting for student and school ESCS. However, participation in 'a scheduled meeting or conference for parents' is associated with a 10-point advantage on science for students of participating parents in Ireland relative to non-participating parents.

9.1.7. Students' engagement, motivation and attitudes towards science in PISA 2015

Around eight out of ten students in Ireland, and more female students than male students, study or intend to study a science subject to Leaving Certificate level. However, fewer than one-third of students in Ireland expect to be in a science-related career at age 30. Among those expecting a career in science, health-care professions such as nursing, physiotherapy and medicine are the most popular choices. Students in Ireland, and across OECD countries on average, report infrequent participation in science-related activities inside or outside of school. However, participation in science-related activities is significantly associated with achievement in science. When students in Ireland engage with science activities, it tends to be via the Internet more so than through books or magazines, or though science clubs, and participation in science activities is significantly higher among male students than female students.

Students in Ireland report greater enjoyment of science (intrinsic motivation) and greater interest in broad science topics (e.g., how science can help prevent disease) than do students on average across OECD countries. In Ireland, male students report more intrinsic motivation for science learning than female students, but they do not differ from female students in how useful they perceive science to be for their future study and career plans (instrumental motivation). Students in Ireland have greater instrumental motivation for science learning than do students on average across OECD countries. Scores on the motivation indices have positive associations with performance in science among students in Ireland, with correlations in the moderate[44] (Enjoyment of Science and Interest in Broad Science Topics) and weak-to-moderate (Instrumental Motivation) ranges.

In Ireland, performance on PISA science is significantly associated with Science Self-efficacy (students' beliefs in their ability to use scientific knowledge to complete real world science tasks), and with students' Epistemic Beliefs (the extent to which students value scientific approaches to enquiry). Ireland's score on Science Self-efficacy does not differ significantly from the OECD average. However, students in Ireland score well above the OECD average on Epistemic Beliefs and have one of the higher mean scores on the scale among all participating countries/economies. In Ireland, male students score significantly higher on Science Self-efficacy than female students, but male students and female students do not differ significantly on Epistemic Beliefs. Students in Ireland also score above the OECD averages on indices of Environmental Awareness and Environmental Optimism, indicating that they have a higher degree of familiarity with various environmental issues such as air pollution, and are more optimistic about improvements in these issues. However, Environmental Optimism is not positively related to achievement in science.

9.1.8. Trends in science performance

The difference in performance in Ireland between 2006 and 2015 (the OECD's preferred comparison window)[45] of 5.8 score points is not statistically significant. The OECD average difference fell by a non-significant 4.8 score points. Several countries experienced significant negative changes in this period, including Finland (-32.7), New Zealand (-17.1), and Austria (-15.8).

On average across OECD countries, there was a significant drop of 8.0 score points in science performance between 2012, when science was a 'minor domain', and 2015, when it was a 'major domain'. Only Portugal showed a significant improvement. Ireland's mean score decreased by 19.4 score points between 2012 and 2015, which is significant, as did the scores of Hong Kong (China) (-31.7), Poland (-24.4), and Korea (-22.0), and seven other comparision countries.

The analysis of trends by proficiency level and by gender provides information on areas of relative strength and weakness in science performance – both between 2006 and 2015 and between 2012 and 2015. In Ireland, the percentage of students performing below Level 2 ('low' performers in science) remained relatively stable, at 15.5% in 2006, and 15.3% in 2015, though, in 2012, just 11.1% performed below Level 2. In contrast, the proportion of students in Ireland performing at or above Proficiency Level 5 ('high' performers) decreased to 7.1% in 2015 from 9.4% in 2006, and 10.7% in 2012. There are fewer higher performers in science in Ireland in 2015, compared with 2006 and 2012.

In 2006, female students in Ireland had a mean score that was higher than male students by a non-significant 0.4 score points. In PISA 2015, there was a 10.5 points difference in favour of male students. The corresponding OECD average in 2015 is 3.5 score points in favour of males. Linked to this, similar proportions of male and female students in Ireland performed below Level 2 in both 2006 (16.5% of males and 14.5% of females) and 2015 (10.3% and 8.5% respectively). However, while similar proportions of males (10.3% in 2006 and 9.0% in 2015) performed at Level 5 or above, significantly fewer females did so (8.5% and 5.0% respectively).

[44] Correlation coefficients between 0.26 and 0.40 are considered moderate, and those between 0.11 and 0.25 are considered weak-to-moderate.
[45] According to the OECD (2016b), it is safer to compare performance from 'major' to 'major' (2006-2015 in the case of science) than from 'minor' to 'major' (2012-2015 for science).

The difference in science performance between 2012 and 2015 needs to be considered in the context of the changes made in PISA in 2015, including the transition to computer-based testing in most participating countries, the introduction of new, more interactive items that require students to perform virtual experiments and respond to questions that assess their understanding of the outcomes, and changes to the PISA's design and scaling procedures. It is surprising that the scores of higher-performing students seem to have been affected by the transition to computer-based assessment to a greater extent than those of lower-performing students. It may be that the transition to computer rendered higher-level questions in PISA more challenging, while leaving lower-order ones at the same level as previously.

9.1.9. Trends in reading literacy performance

Reading literacy was a minor assessment domain in PISA 2015. Ireland's mean score increased substantially between 2009 (the last cycle in which it was a major domain) and 2012, returning to the level achieved between 2000 and 2006. Ireland's mean score was marginally, but not significantly, lower (by 2.4 score points) in 2015, compared with 2012. It is notable that just five countries experienced significant declines in reading performance between 2012 and 2015, including Japan (-22.1), Korea (-18.4), and Switzerland (-16.8), while three had significant increases – Slovenia (23.9), the Russian Federation (35.2) and Sweden (16.8).

While female students in Ireland and on average across OECD countries performed significantly better than males on PISA 2015 reading, the gender gap in Ireland was smaller in 2015 (12.0 score points) than in 2012 (28.5) or in earlier cycles and is now well below the average across OECD countries (27.1 score points in 2015, down from 39.3 in 2012). Hence, the gender gap narrowed both in Ireland and on average across OECD countries in the course of transitioning to computer-based testing (albeit with the same texts that appeared on paper in earlier cycles). In 2015, 3.7% fewer female students performed at Level 5 or above, compared with 2012. There was an increase of 2.2% in the proportion of males performing at Level 5 or above between these years.

The relatively-strong performance of students in Ireland on reading literacy is not unexpected. In PISA 2012, students in Ireland did well on an experimental test of computer-based literacy. Furthermore there is evidence of improved performance at primary level (Shiel & Kavanagh, 2014). While, on the one hand, it is encouraging to see male students performing more strongly in reading literacy in 2015 than in earlier cycles, when the test was mainly offered on paper, the finding that fewer female students achieved Levels 5-6 relative to earlier cycles needs to be considered by policy-makers, perhaps in the context of the broader move towards computer-based teaching, learning and assessment described in the *Digital Strategy for Schools* (DES, 2015b).

9.1.10. Trends in mathematics performance

PISA 2015 was the first cycle in which all participating students in Ireland had studied under the new mathematics curriculum for Junior Certificate and Leaving Certificate, colloquially known as 'Project Maths'. However, it is difficult to gauge the impact of the new curriculum on performance, given the other changes to PISA in 2015, including the transition to a computer-based platform. Mathematics was a minor assessment domain in 2015.

Ireland's mean scores on PISA mathematics in 2003 (502.8) and 2006 (501.5) were not significantly different from the corresponding OECD averages. In 2009, Ireland's mean score (487.1) was significantly below the OECD average. In 2012, when it increased to 501.5, it was significantly above the OECD average for the first time, and in 2015, it improved slightly, to 503.7, and maintained its position relative to the OECD average. Ireland's relatively stable performance between 2012 and 2015 is remarkable in that 8 of the top 30 highest-performing countries in 2012 experienced declines in 2015, including Korea (-29.7), Hong Kong (China) (-13.3), Poland (-13), the Netherlands (-10.7) and Australia (-10.3), and five experienced significant increases, including Sweden (+15.7), Norway (+12.4) and Denmark (+11.1). As with reading literacy, it is unclear if the transition to computer-based assessment is responsible for these changes, and, if so, why.

In 2015 in Ireland, there was a gender gap of 16.1 score points in favour of male students in mathematics, up from 15.3 points in 2012, and well above the OECD average of 7.7 (which fell back from 10.3 in 2012). Indeed, in 2015, in contrast with the situation in reading, Ireland had one of the largest gender gaps in mathematics among OECD countries. Again, it is notable that just 6.5% of female students in Ireland performed at or above Level 5 on mathematics, down from 8.5% in 2012 (when mathematics was a 'major domain'), and well below the OECD average of 9.0% in 2015, which itself dropped from 10.8% in 2012. In 2015, there was a slight increase in the proportion of male students in Ireland performing at Level 5 or above compared with 2012 (12.7% to 12.9%), while on average across OECD countries, there was a significant drop between these years, from 14.9% in 2012 to 12.6% in 2015.

There was a drop of 4.8 points in Ireland's standard deviation in mathematics between 2012 and 2015, and it is now 79.8 points – well below the OECD average of 98.4.

It may be that Ireland's relatively stable performance on PISA mathematics between 2012 and 2015 can be attributed to the knowledge and skills that students acquired through their participation in the new mathematics curriculum ('Project Maths'), enabling them to better handle the requirements of PISA mathematics than their counterparts in earlier PISA cycles, despite the move to computer-based testing. Again, however, the widening gender gap in mathematics is notable. Factors associated with this may include female students' ongoing difficulties with the Shape and Space component of PISA mathematics (though many male students struggle with this too), their higher levels of anxiety about mathematics (Perkins et al., 2013) and the challenges posed by computer-based testing.

9.1.11. Trends in school and student characteristics

In general, the characteristics of the PISA 2015 sample in Ireland were found to be similar to those of earlier PISA cycles. However, there was a notable increase in the proportion of students described as immigrant speakers of English or Irish (up from 3.6% in 2006 to 7.3% in 2015) and immigrant speakers of other languages (up from 1.7% to 7.1% between the same years), though the latter group may have included some exchange students from other EU countries who were studying in Ireland for part of the 2014-15 school year. The proportion of students in Transition year also increased, from 21.2% in 2006 to 26.7% in 2015, with a parallel fall in the proportion in Fifth year (from 17.5% to 10.9%). When the OECD reweighted Ireland's data for previous PISA cycles to the observed composition of the PISA 2015 sample, the revised mean scores were close to the original estimates, suggesting that demographic change had little impact on performance across cycles.

The proportion studying science in the Junior Certificate examination increased from 82.6% in 2006 to 91.2% in 2015. Further, among those taking science, the proportion taking the Higher-level science paper increased from 67.3% in 2006 to 78.6% in 2015. There is no clear evidence that any of these changes impacted in a negative way on PISA science performance in Ireland between 2012 and 2015.

9.1.12. Trends in students' engagement, motivation and attitudes towards science

Students in Ireland report a large and significant increase in their Enjoyment of Science between 2006 and 2015 and Ireland's mean score on this index is now significantly above the OECD average. It is noteworthy that Instrumental Motivation to learn science has increased significantly, perhaps because students are more aware of the importance of science in the context of their future careers. Although there has been an increase in Ireland's mean score on the PISA index of Science Activities, it still lags behind the corresponding OECD average score, and students in Ireland continue to report low involvement in activities such as visiting websites about science topics, reading science magazines, and attending science clubs. There has been a small but significant increase, from 23.8% in 2006 to 27.3% in 2015, in the proportion of students in Ireland expecting to be in science-related occupations by age 30. Roughly equivalent proportions of male (28.0%) and female students (26.6%) expect to work in these occupations, with more male students expressing a preference for engineering and ICT careers, and more females favouring a career as a health professional.

9.2. Conclusions

This sections examines four broad themes that arise from the outcomes of PISA 2015 in Ireland: the effects of computer-based testing; high and low performers; gender differences in performance; and attitudes towards and engagement with science.

9.2.1. Computers and PISA science

It is unclear to what extent the transition to computer-based testing in PISA 2015 contributed to observed changes in performance in Ireland. On the one hand, performance on reading literacy and mathematics (as minor domains) in Ireland was about the same in 2012 and 2015. On the other, performance on science fell by 19.4 score points, one of the largest declines among participating countries over that three-year period. A number of countries, including Finland, the Czech Republic, Hong Kong (China) and New Zealand experienced similarly-sized declines in science between 2006 and 2015.

Students in Ireland achieved a percent correct score of 54.9% in 2015 on a cluster of 53 trend science items that had been administered in each PISA cycle since 2006. This represented a decline of 2.3% on the item cluster since 2012. However, other countries that performed at the same level as Ireland in 2012 experienced declines on the trend items that were equivalent in size to Ireland's or greater (Canada fell by 2.7%, the Netherlands by 4.2% and the Germany by 4.7%), yet Canada and Australia performed at a significantly higher level than Ireland on the overall science scale, while the Netherlands and Germany ranked ahead of Ireland.

The science items that were most problematic for Ireland are the new ones. These were developed specifically to capitalise on the affordances of the computer-based testing platform. There were 99 new science items, and, of these, 75 were non-interactive, and 24 interactive. Students in Ireland struggled with items in both categories, and lagged behind all four comparison countries on both. Ireland's relatively weak performance on the new items enabled the other four countries to compensate for their relatively poor performance on the multi-year trend items, and enabled Canada in particular to perform at about the same level as in 2015.

It might be argued that the inclusion of the new science items, and the interactive simulated experiments in particular, was unfair, in that it represented a possible change to the construct underlying PISA science. For example, students were required to engage with and record the outcomes of simulated experiments that students in earlier PISA cycles did not have to contend with. The inclusion of such items might explain why so many countries experienced significant declines in performance in 2015. New, more complex and more challenging items were introduced and students in Ireland struggled on them compared with more traditional items. However, given the advances made by technology and its incorporation into teaching, learning and, to a lesser extent, assessment, the landscape in which students study science and other subjects is undergoing substantial change. The skillsets students will need in their future lives are also changing. Such changes are reflective of broader advances in society, and therefore should be considered when planning the assessments that students encounter in schools.

However, the inclusion of new science items does not explain why many countries, including high-performers such as Canada and Australia, and, to a lesser extent, Ireland, did less well on the 53 link items in 2012, compared with earlier PISA cycles. One possibility is that the transfer of paper-based items to computer resulted in a higher level of complexity, incorporating some of the challenges identified in the item review described in Chapter 3. Although the review focused on science, it is clear that several of the issues that were identified are applicable to other domains as well. These include a heavy and repetitive reading load at the beginning of some units, ambiguity relating to where students should allocate their attention on the screen, a lack of opportunity to review units that had been completed already, possible ambiguity around the wording of some questions, and uncertainty as to how much text to produce when answering open-ended items. It is possible that students in Ireland, who are used to clearly-written and logically-structured examination papers, struggled with structure of the PISA items on computer, as well as aspects of the computer platform.

It was noted in Chapter 7 that students in Ireland did not engage as frequently as students on average across OECD countries in a number of science-related activities (whether completed at home or in school). These included simulating natural phenomena and technical processes in computer programmes/virtual labs,. It might be hypothesised that additional experience with activities such as these might enable students to cope better with the requirements of items such as those administered in PISA. Similarly, while it was noted in Chapter 6 that the scores of students in Ireland on indices of Interest in ICTs, Perceived Competence in ICT, and Perceived Autonomy with Regard to ICT were above the corresponding OECD average scores, students in Ireland had scores that were below the corresponding averages on indices of Use of ICT at School in General, and ICT Use Outside of School for Schoolwork.

However, it is unlikely that greater use of computers by students in post-primary schools will, by itself, lead to enhanced understanding of scientific processes or stronger performance on tests that assess higher-order thinking skills. There is a need to ensure that students adopt problem solving strategies when they encounter science problems such as the new PISA science items, and they reflect on how they arrive at answers. This contrasts with the observation by some PISA test administrators (see Chapter 3) that many students tended to move through the PISA computer-based items at a very fast rate, and did not seem to allocate the level of attention that the questions demanded.

9.2.2. High and low performers

As noted in Chapter 8, there are fewer lower-achieving students in Ireland (those performing below Proficiency Level 2), compared with the average across OECD countries across all domains. And, for the most part, the proportions of students performing poorly are stable (exceptions are 2009 reading and mathematics, and 2015 science). It is remarkable that the proportions of lower-achieving students have remained constant even though there have been significant demographic changes, including, for example, an increase from 1.7% to 7.1% between 2006 and 2015 in the proportion of students who speak a language other than English or Irish. The priority given to teaching basic literacy and numeracy skills, and the supports available to struggling learners may well have contributed to ensuring that there are low proportions of lower-achieving students in the system. The return of the proportion performing below Level 2 in science to pre-2012 levels needs to be interpreted with regard to the transition to computer-based testing and the introduction of new science items. These factors have impacted on all students in Ireland taking PISA science in 2015.

A different situation is emerging with regard to higher-achieving students. In the case of science, the proportion achieving Levels 5-6 in 2015 is 7.7%, just above the corresponding OECD average of 7.1%. Similarly, 9.8% in Ireland perform at Levels 5-6 on mathematics, compared with an OECD average of 10.7%. Only reading literacy has a significantly higher proportion performing at Levels 5-6 in 2015 (10.7%) compared to the corresponding OECD average. The performance in mathematics is a particular concern since the OECD average excludes several higher-performing countries in mathematics which are outside of the OECD, including Singapore, Hong-Kong China and Japan.

The relatively low proportion of higher achievers in Ireland, especially on paper-based mathematics and science, has been pointed out in reports on earlier PISA cycles (e.g., Perkins et al. 2013). In PISA 2012 computer-based mathematics, students performing at the 90th percentile in Ireland achieved a significantly lower score than on average across OECD countries even though overall performance was not significantly different from the OECD average. A number of factors seem to contribute to low performance among high achievers in mathematics, including underperformance on certain mathematical content areas (Space and Shape has been a consistent problem area in previous cycles, while Change and Relationships was identified as a potential problem in 2016; a breakdown on performance in these areas is not available for PISA 2015). Another relevant factor is the high level of anxiety about mathematics among female students in Ireland (Perkins et al., 2013) which may carry over into the types of real-life problems that are encountered in PISA.

The low proportion of high performers on PISA 2015 science, and a score at the 90th percentile (617.6) that is not significantly different from the OECD average (614.8), even though Ireland's overall mean score is significantly above the OECD average, indicates that high performers in Ireland may not be achieving their potential. The transition to computer-based assessment has undoubtedly contributed to the problem. It is unclear at this stage if the change in Ireland in the proportion performing at Levels 5-6 between 2012 and 2015 (from 10.7% to 7.1%) is due in its entirety to computer-based testing or if other factors are also involved. For example, the higher-level scientific thinking processes in which students in Ireland should engage may be constrained by nature of the science tasks they encounter in curriculum and other contexts.

9.2.4. Gender differences

The pattern of gender differences in Ireland has changed in substantive ways since earlier rounds of PISA. The gender difference on reading literacy (12.0 score points in favour of female students) is now among the smallest among participating countries, and is well below the corresponding OECD average of 26.9. Back in 2009, there was a gender difference in Ireland of 39.2 score points in favour of females, compared with an OECD average of 24.5 score points in that year. On digital reading in 2012, female students in Ireland had a mean score that was 25.3 score points higher than that of male students, while the corresponding OECD average difference was not significantly different at 26.0 score points. The narrower gender gap in Ireland in PISA 2015 reflects a stronger performance among male students, as well as a lower score among female students. One issue that could be examined is whether female students taking reading after science in PISA 2015 were affected to a greater extent by computer-based testing than females taking reading before science, as the science test (and especially the new science items) may have dented female students' confidence to a greater extent than male students'.

In science, the gender difference in Ireland is statistically significant for the first time in PISA 2015 (10.5 score points in favour of males) and is larger than the corresponding OECD average difference 3.5 score points). Compared with 2006, the performance of males is about the same on PISA science, while the performance of females had dropped by about 10 score points. It is also noteworthy that fewer female students perform at Levels 5-6 on PISA 2015 science (5.0% compared with 9.0% of males), and that marginally fewer female students in Ireland than on average across OECD countries perform at Levels 5-6 (5.0% compared with 6.5%). These differences might be related to patterns of lower perceived ICT competence among female students, and lower perceived autonomy with regard to ICT, as well as generally low engagement with ICT in school in general, as well as ICT use outside of home for schoolwork (though female students in Ireland were significantly ahead of male students on this measure). The unpredictability and increased complexity of PISA science tasks may also impact on female students in Ireland (and higher-achieving female students in particular) to a greater extent than male students. This can be examined further by looking at percent correct scores by gender on clusters of PISA science items, including the new interactive items.

The gender difference on PISA 2015 mathematics is 16.1 score points in favour of male students, and is higher than the OECD average of 6.9 points. Moreover, while the proportion of female students performing below Level 2 in Ireland (15.8%) is below the corresponding OECD average (23.7%), the proportion of females in Ireland performing at Levels 5-6 (6.5%) is also below the OECD average of 8.9%. It is likely that some of the same issues that may affect the performance of female students in Ireland on PISA science are also likely to impact on mathematics. In addition, as noted earlier, PISA 2012 showed that female students in Ireland have higher levels of anxiety about mathematics than male students along with lower levels of mathematics self-efficacy and mathematics self-concept. Hence, it may be important to raise female students' confidence with ICTs, and their confidence with mathematics, in the context of solving complex real-life mathematics problems.

9.2.5. Attitudes towards and engagement in science

There was a slight but significant increase in the engagement of students in Ireland on the PISA index of Engagement in Science-related Activities between 2006 and 2015. However, Ireland's mean score on this index in 2015 is still well below the average for OECD countries. Moreover, there has been a small shift in Ireland away from reading science magazines or science articles in newspapers to sourcing information about science topics on the Internet. It may be that the curriculum changes at Junior Certificate level described in Chapter 2 will encourage students to engage more frequently in science-related activities as they engage more in enquiry learning, including enquiries on socio-scientific issues. It is encouraging that students in Ireland had higher mean scores in 2015 on Enjoyment of Science and on Instrumental Motivation to learn science, compared with 2012, and curriculum changes can be expected to impact on these aspects as well over the next several years. The key challenge may now be to seek ways to address gender differences in areas such as Enjoyment of Science and Interest in Science Topics, two scales on which females do less well than males, and which are significantly related to science performance.

9.3. Looking towards PISA 2018

Preparation for the next cycle of PISA, which will take place in March 2018 in Ireland, is already underway. Reading literacy will be the main domain, with science and mathematics assessed as the minor domains. As the second cycle of PISA to be fully administered on computers, PISA 2018 will be the first time reading literacy will be assessed as a main domain on computer. Similar to scientific literacy in PISA 2015, new items will be developed specifically for the assessment of reading literacy on a computer-based platform, within a new assessment framework. Tasks based on the new reading framework include reading from multiple sources, integrating information across multiple sources, and evaluating the veracity of texts. The new framework also includes an assessment of reading fluency that seeks to assess students' ease and efficiency of reading. The assessment of fluency aims to investigate if students hold the foundational skills that are a prerequisite to comprehending the overall meaning of a text. A student's score on a fluency subscale can be used to help interpret overall student performance in reading literacy.

The Effort Thermometer, administered to students during PISA assessments in previous cycles (Norway, Germany and Australia in 2000; and in all countries in 2003, 2006 and 2012) is set to be administered to students as part of PISA 2018. This assesses students' motivation as a self-reported measure and, along with a national Test-taking Behaviour Questionnaire, may prove useful in interpreting PISA results in 2018.

In the Field Trial in March 2017, adaptive testing in PISA will be examined in the main domain of reading literacy. This creates the opportunity to explore the suitability of adaptive testing in PISA. Adaptive testing, with the alignment of items to the ability range of the students, may allow for higher levels of measurement precision using fewer items. Adaptive testing will be trialled using a multi-stage approach; students will answer an initial set of items and the difficulty of the next set of items will be dependent on performance on the previous set. This alignment will occur multiple times throughout the assessment. Adaptive testing endeavours to make the assessment more sensitive to the needs of students, as students at the lower end of the performance distribution will be given items that are at a lower difficulty level, while those at the higher end will see items that are at a high difficulty level, compared to the traditional test form that includes items drawn from a wider range of difficulty.

A new student well-being questionnaire is being developed as part of PISA 2018. Depending on the outcomes of the Field Trial, this questionnaire may form part of the Main Study administration in 2018. The parent questionnaire, which was first administered in Ireland in PISA 2015, will also be administered for the second time as part of the 2018 cycle.

Global competence is set to be included as the innovative (minor) domain that will be administered to students as part of PISA 2018. Global competence seeks to assess students' knowledge and understanding of global issues and their ability to analyse global issues critically and from multiple perspectives. Engagement in appropriate and effective communications with others is also included. A pilot study of global competence will be implemented in a small number of countries (not including Ireland) in spring 2017, and may also form part of the Main Study administration in 2018.

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Appendix A: Membership of the PISA 2015 National Advisory Committee

In Ireland, PISA is administered on behalf of the Department of Education and Skills (DES) by the Educational Research Centre. The DES and the ERC are supported in their work by a National Advisory Committee. Members of the PISA 2015 National Advisory Committee are:

Suzanne Dillon (Department of Education and Skills, Chair, from June 2016)

Pádraig MacFhlannchadha (Department of Education and Skills, Chair, to June 2016)

Declan Cahalane (Department of Education and Skills)

Conor Galvin (University College Dublin)

Rachel Linney (National Council for Curriculum and assessment, until October 2015)

Bill Lynch (National Council for Curriculum and Assessment, until July 2015)

Odilla Finlayson (Dublin City University)

Deirdre Henchy (State Examinations Commission, from April 2016)

Philip Matthews (Trinity College Dublin)

Hugh McManus (State Examinations Commission, until April, 2016)

Tom McCloughlin (Dublin City University)

Brian Murphy (University College Cork)

Elizabeth Oldham (Trinity College Dublin)

Liz O'Neill (Department of Education and Skills)

Maurice O'Reilly (Dublin City University)

Ruth Richards (Department of Education and Skills)

Barry Slattery (National Council for Curriculum and Assessment, from October 2015)

Peter Archer (ERC, PISA Governing Board representative from November 2014)

Jude Cosgrove (ERC, until June 2015, National Project Manager until November 2014)

Caroline McKeown (ERC)

Brían Merriman (ERC, until May 2015)

Adrian O'Flaherty (ERC)

Gerry Shiel (ERC, PISA Governing Board representative until November 2014; National Project Manager from November 2014)

Appendix B: Sample Units and Questions from PISA 2015 Science

This appendix includes sample items from PISA 2015. Three units are presented:

- Running in Hot Weather[46] - Interactive – PISA Field Trial (2014)
- Slope-face Investigation – PISA Main Study (2015)
- Sustainable Fish Farming – PISA Main Study (2015)

Each unit comprises one or more introductory screens, and some items. For each item, information is given on the following (see Chapter 1 for definitions):

- The question type (whether regular multiple-choice, complex multiple choice, or open constructed response)
- The competency cluster to which the item belongs (whether explain phenomena scientifically; evaluate and design scientific inquiry; or interpret data and evidence scientifically)
- The type of scientific knowledge assessed (whether Content Knowledge, Procedural Knowledge or Epistemic Knowledge)
- The content knowledge system assessed (whether Physical Systems, Living Systems or Earth and Space Systems)
- The difficulty of the item in terms of a scale score (PISA places student scores and item scores on the same underlying scale) and a proficiency level (see Chapter 4 for details on science proficiency levels). These measures of difficulty reflect average performance across OECD countries.
- The weighted percent correct score in Ireland and on average across OECD countries. These data are not available for Running in Hot Weather, as it was used in the PISA 2015 Field Trial only and was administered to a non-representative sample.
- The scoring scheme (in the case of constructed response items)

There are no sample items for PISA 2015 reading literacy and mathematics. This is because the items used to assess performance on these minor domains are secure items held over from the 2009 (reading literacy).

Readers can complete PISA 2015 released science items, including those presented in this Appendix, in electronic mode, and view items from earlier assessments at www.oecd.org/pisa

[46] Data for Ireland are unavailable on this unit, as it was administered to a convenience sample in the PISA 2015 Field Trial in spring 2014). It is the only example of an interactive item that the OECD has released.

Running In Hot Weather - Introduction

PISA 2015

Running in Hot Weather
Introduction

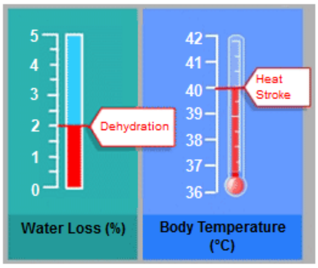
Read the introduction. Then click on the NEXT arrow.

RUNNING IN HOT WEATHER

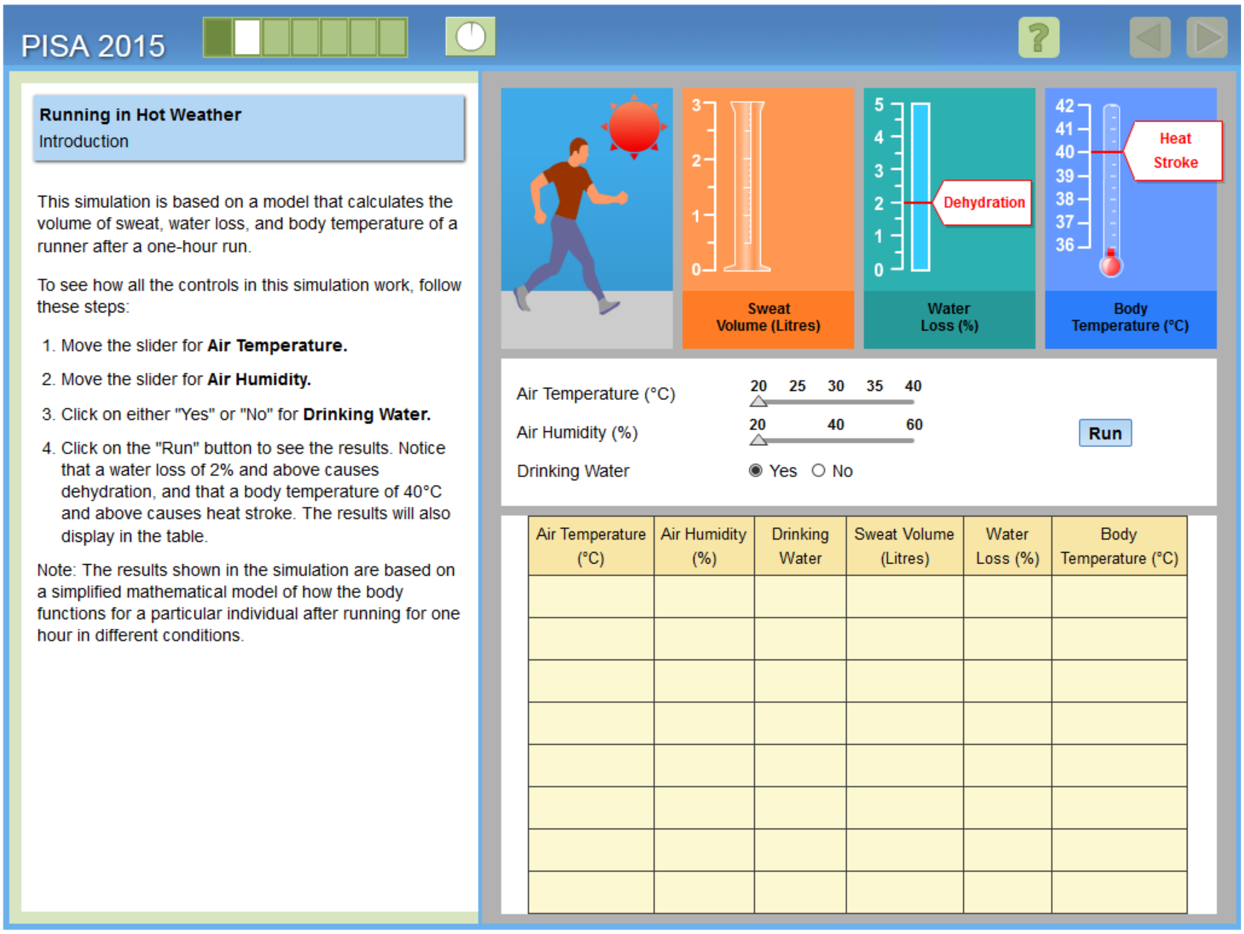
During long-distance running, body temperature rises and sweating occurs.

If runners do not drink enough to replace the water they lose through sweating, they can experience dehydration. Water loss of 2% of body mass and above is considered to be a state of dehydration. This percentage is labeled on the water loss meter shown below.

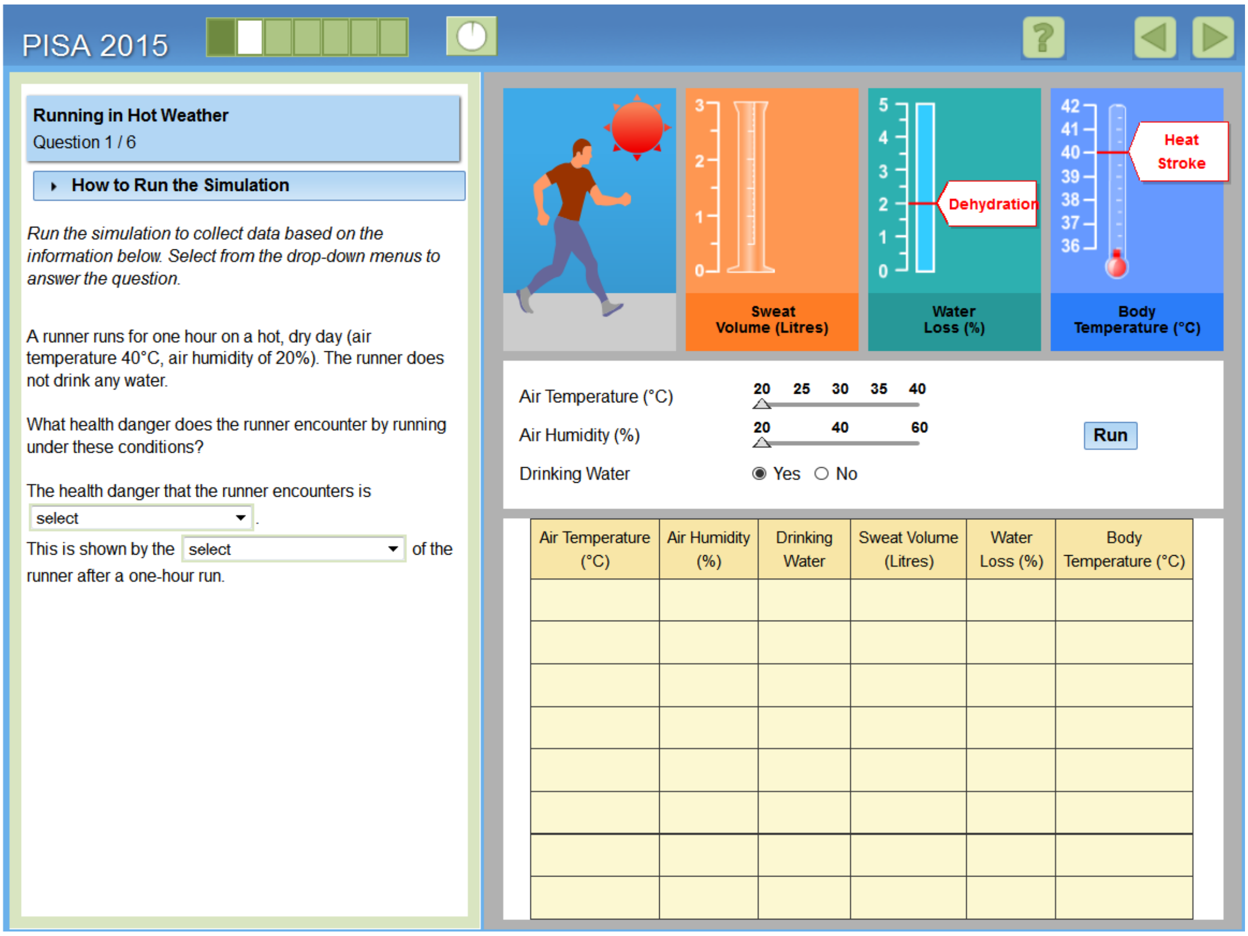
If the body temperature rises to 40°C and above, runners can experience a life-threatening condition called heat stroke. This temperature is labeled on the body temperature thermometer shown below.



Running in Hot Weather - Practice



Running in Hot Weather – Question 1



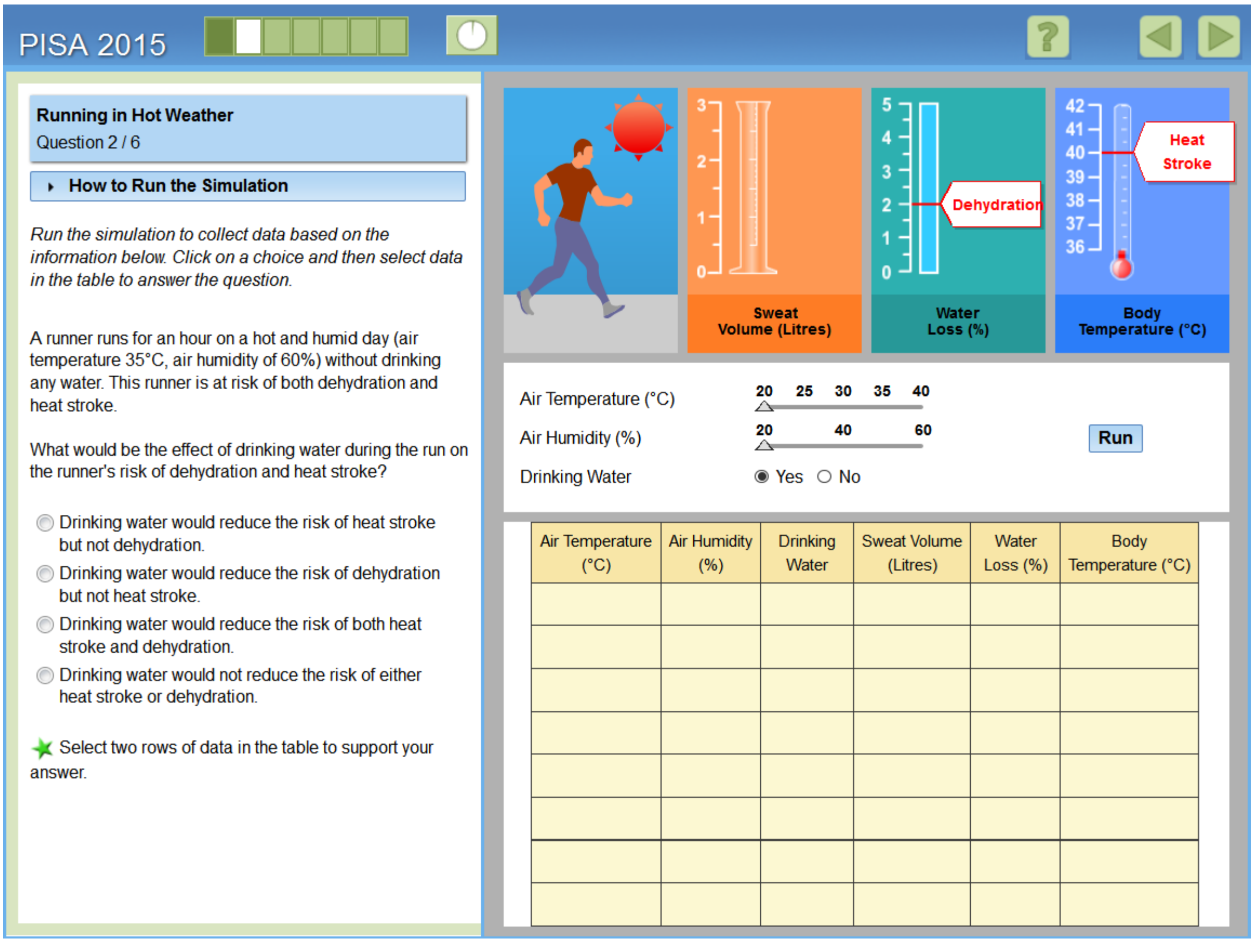
Question Type	Complex Multiple Choice
Competency	Interpret Data and Evidence Scientifically
Knowledge – System	Procedural - Living
Context	Personal – Health and Disease
Difficulty	495 – Level 3
Question ID	

Scoring

Full credit: The health danger that the runner encounters is (*dehydration/heat stroke*).[47] This is shown by the (*sweat volume/water loss/body temperature*) of the runner after a one-hour run.

[47] Note that underlining indicates the correct response.

Running in Hot Weather – Question 2



Question Type	Simple Multiple Choice/Open Response
Competency	Interpret Data and Evidence Scientifically
Knowledge – System	Content – Living
Context	Personal – Health and Disease
Difficulty	581 – Level 4
Question ID	

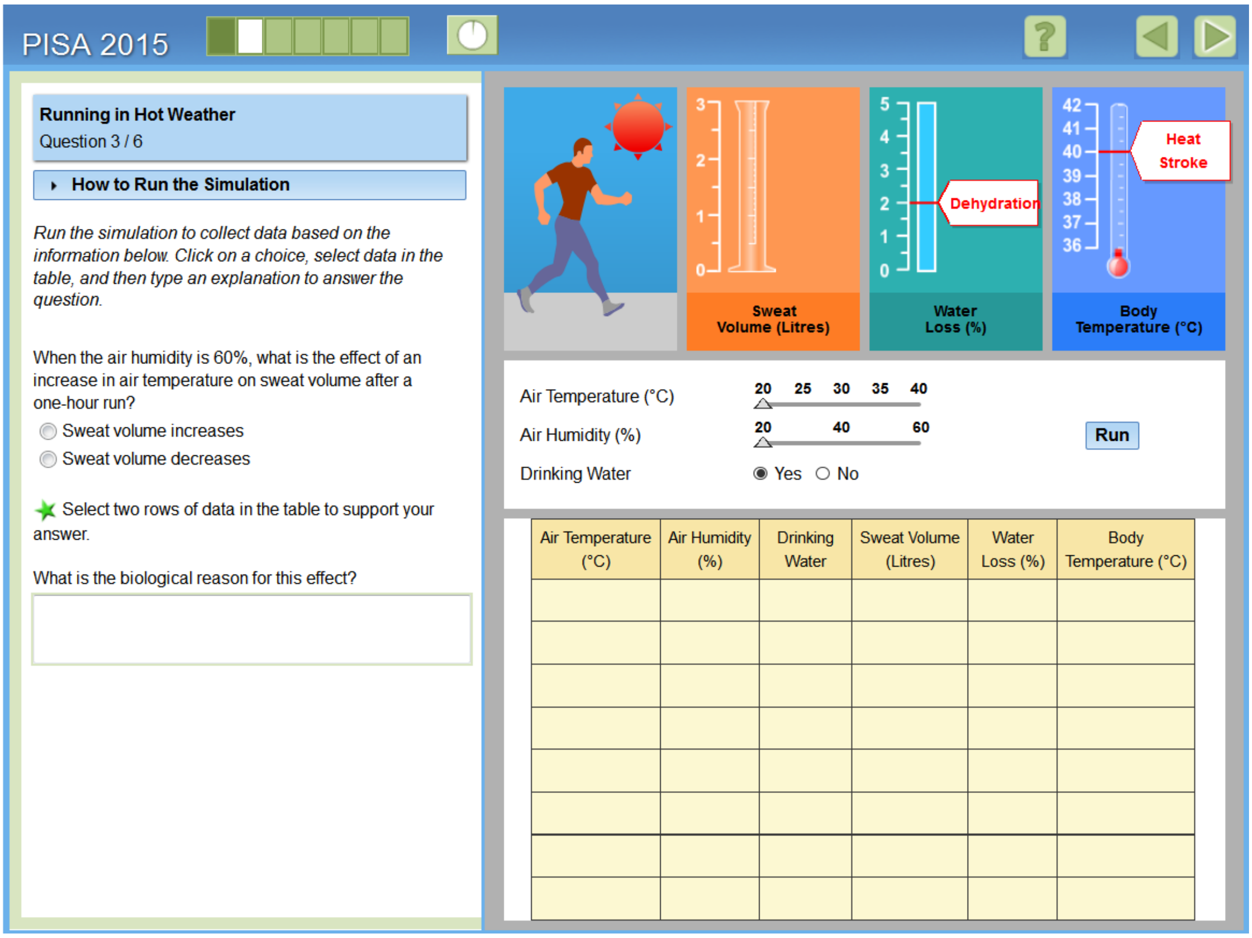
Scoring

Full Credit: The student selects:

Drinking water would reduce the risk of dehydration but not heat stroke AND selects the following two rows in the data table:

- Air temperature set to 35° C, 60% air humidity and “No” for drinking water AND
- Air temperature set to 35° C, 60% air humidity and “Yes” for drinking water

Running in Hot Weather – Questions 3a and 3b



Question 3A

Question Type	Multiple Choice and Open Response (select data) – Computer Scored
Competency	Evaluate and Design Scientific Enquiry
Knowledge – System	Procedural – Living
Context	Personal – Health and Disease
Difficulty	530 – Level 3
Question ID	

Question 3B

***3B** Question Type*	Open Response – Human Coded
Competency	Explain Phenomena Scientifically
Knowledge – System	Content – Living
Context	Personal – Health and Disease
Difficulty	644 – Level 5
Question ID	

Scoring

Question 3A

Full Credit: The student selects:

Sweat volume increases

AND

The two selected rows must have air humidity of 60% and two different air temperatures selected (one lower and one higher – such as 20°C in one row and 25°C in the second or 35°C in one row and 40°C in the second, etc.) In addition, drinking water must have the same setting (either “Yes” or “No”) in both of the selected rows.

Question 3B

Full Credit: The student’s response indicates or implies the function of sweat in cooling the body and/or regulating body temperature.

Sweat evaporates to cool the body when temperatures are high.
Increasing sweat levels in high temperatures keeps the body from getting too hot.
Sweat helps maintain body temperature at a safe level.

Slope-Face Investigation – Introduction

PISA 2015

Slope-Face Investigation
Introduction

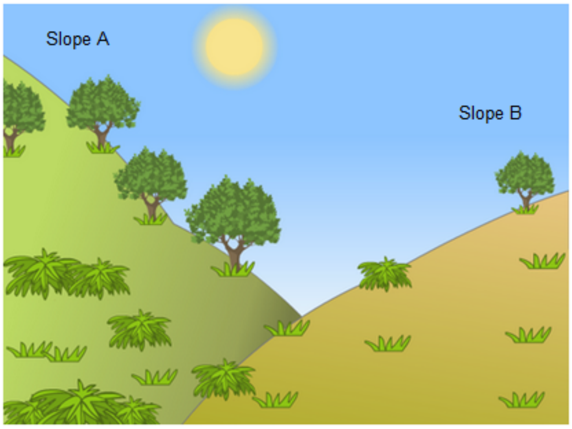
Read the introduction. Then click on the NEXT arrow.

SLOPE-FACE INVESTIGATION

A group of students notices a dramatic difference in the vegetation on the two slopes of a valley: the vegetation is much greener and more abundant on slope A than on slope B. This difference is shown in the illustration on the right.

The students investigate why the vegetation on the slopes is so different from one slope to the other. As part of this investigation, the students measure three environmental factors over a given period of time:

- **Solar radiation:** how much sunlight falls on a given location
- **Soil moisture:** how wet the soil is in a given location
- **Rainfall:** how much rain falls on a given location



Slope-Face Investigation – Question 1

Question Type	Open Response – Human Coded
Competency	Evaluate and design scientific enquiry
Knowledge – System	Epistemic – Earth & Space
Context	Local/ National - Natural Resources
Difficulty	520 – Level 3
Question ID	S637Q01
Percent Correct	Ireland 65.8%; OECD 51.3%

Scoring

Full Credit: The student gives an explanation that identifies a scientific advantage of using more than one measurement instrument on each slope, e.g. correcting for variation of conditions within a slope, increasing the precision of measurement for each slope.

- So they could determine whether a difference between slopes is significant.
- Because there is likely to be variation within a slope.
- To increase the precision of the measurement for each slope.
- The data will be more accurate.
- In case one of the two malfunctions
- To compare different amounts of sun on a slope [A comparison implies that there may be variation.]

Slope-Face Investigation – Question 2

PISA 2015

Slope-Face Investigation
Question 4 / 4

Refer to "Data Analysis" on the right. Click on a choice and then type an explanation to answer the question.

Two students disagree about why there is a difference in soil moisture between the two slopes.

- Student 1 thinks that the difference in soil moisture is due to a difference in solar radiation on the two slopes.
- Student 2 thinks that the difference in soil moisture is due to a difference in rainfall on the two slopes.

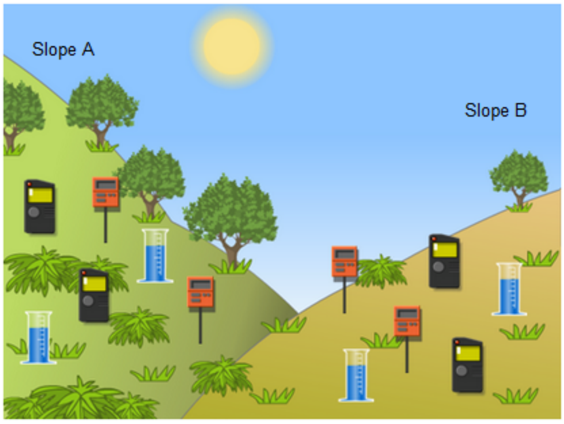
According to the data, which student is correct?

- Student 1
- Student 2

Explain your answer.

SLOPE-FACE INVESTIGATION
Data Analysis

The students take the average of the measurements collected over a given period of time from each pair of instruments on each slope and calculate the uncertainty in these averages. Their results are recorded in the following table. The uncertainty is given following the "±" sign.



	Average Solar Radiation	Average Soil Moisture	Average Rainfall
Slope A	3800 ± 300 MJ/m^2	28 ± 2%	450 ± 40 mm
Slope B	7200 ± 400 MJ/m^2	18 ± 3%	440 ± 50 mm

Question Type	Open Response – Human Coded
Competency	Interpret data and evidence scientifically
Knowledge – System	Epistemic – Earth & Space
Context	Local/National - Natural Resources
Difficulty	594 – Level 4
Question ID	S637Q05
Percent Correct	Ireland 31.8%; OECD 34.7%

Scoring

Full Credit: The student selects **Student 1**

AND

Gives an explanation that indicates that there is a difference in solar radiation between the two slopes **and/or** that rainfall does not show a difference.

- Slope B gets much more solar radiation than slope A, but the same amount of rain.
- There is no difference in the amount of rainfall the two slopes get.
- There is a big difference in how much sunlight slope A gets compared to slope B.

Sustainable Fish Farming - Introduction

PISA 2015

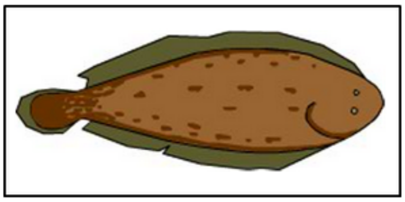
Sustainable Fish Farming
Introduction

Read the introduction. Then click on the NEXT arrow.

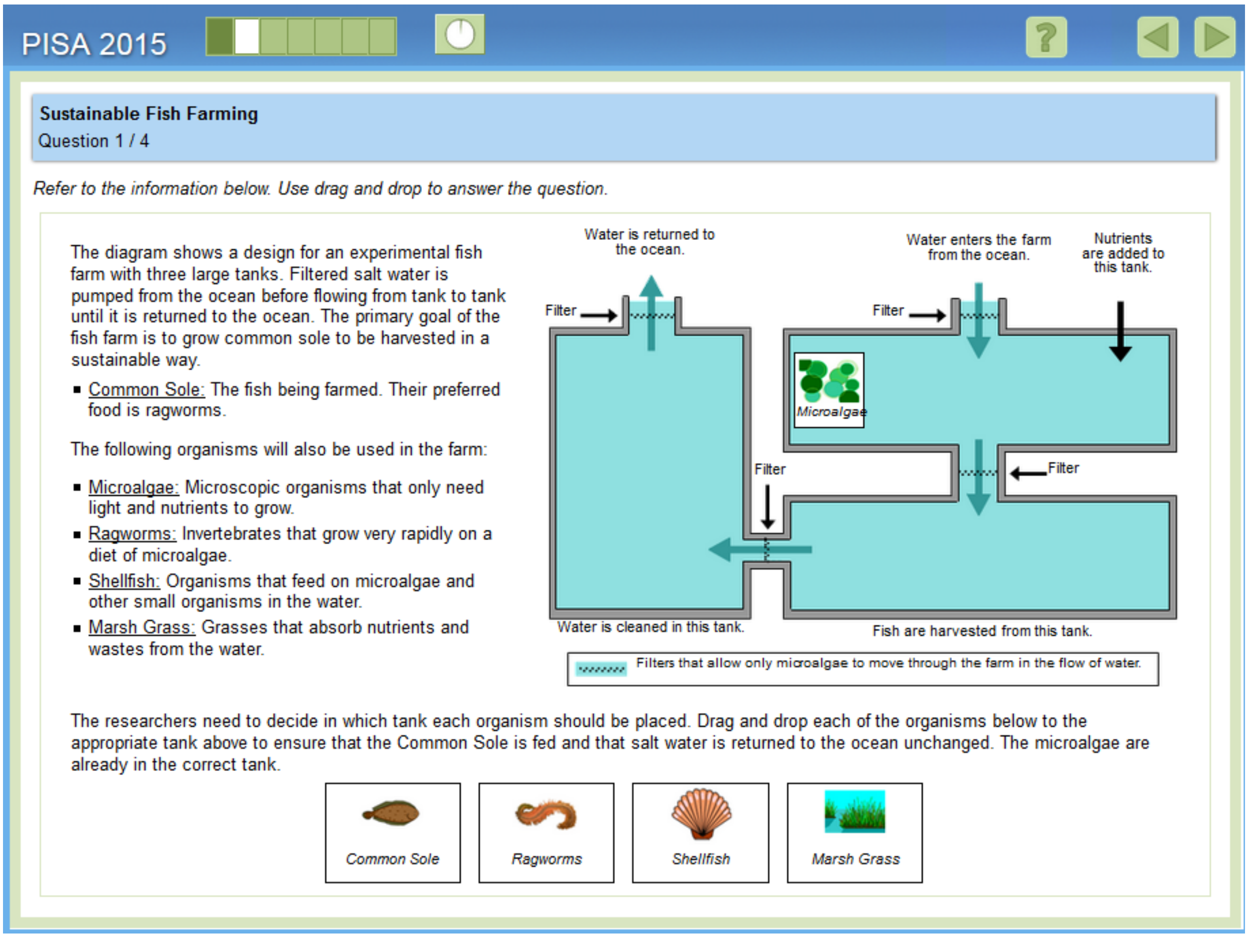
SUSTAINABLE FISH FARMING

An increased demand for seafood is placing a greater burden on populations of wild fish. To reduce this burden, researchers are investigating ways to grow fish sustainably in fish farms.

Two challenges to creating a sustainable fish farm include (1) feeding the farmed fish and (2) maintaining water quality. Farmed fish require large amounts of food. A fish farm that is sustainable will grow the food needed to feed the farmed fish. Waste from the fish can build up in the farm to levels that are dangerous to the fish. In a sustainable fish farm, there is a constant flow of ocean water through the farm. Waste and excess nutrients (food that algae and plants need to grow) are removed from the water before it is returned to the ocean.



Sustainable Fish Farming – Question 1



Question Type	Complex Multiple Choice
Competency	Explain phenomena scientifically
Knowledge – System	Content – Living
Context	Local/ National – Natural Resources
Difficulty	750 – Level 6
Question ID	CS601Q01S
Percent Correct	Ireland 7.0%; OECD 5.9%

Scoring

Full credit: The student drags Ragworms and Common Sole into Tank 2 (bottom right) and drags Marsh Grass and Shellfish into Tank 3 (left)

Sustainable Fish Farming – Question 2

PISA 2015

Sustainable Fish Farming
Question 2 / 4

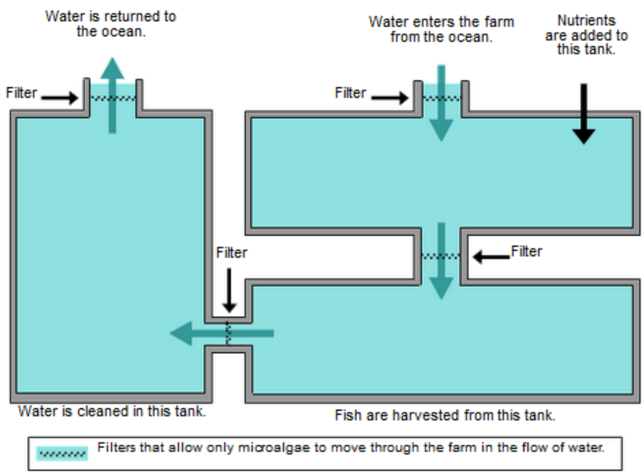
Refer to the information below. Click on a choice to answer the question.

The diagram shows a design for an experimental fish farm with three large tanks. Filtered salt water is pumped from the ocean before flowing from tank to tank until it is returned to the ocean. The primary goal of the fish farm is to grow common sole to be harvested in a sustainable way.

- Common Sole: The fish being farmed. Their preferred food is ragworms.

The following organisms will also be used in the farm:

- Microalgae: Microscopic organisms that only need light and nutrients to grow.
- Ragworms: Invertebrates that grow very rapidly on a diet of microalgae.
- Shellfish: Organisms that feed on microalgae and other small organisms in the water.
- Marsh Grass: Grasses that absorb nutrients and wastes from the water.



Researchers have noticed that the water that is being returned to the ocean contains a large quantity of nutrients. Adding which of the following to the farm will reduce this problem?

- More nutrients
- More ragworms
- More shellfish
- More marsh grass

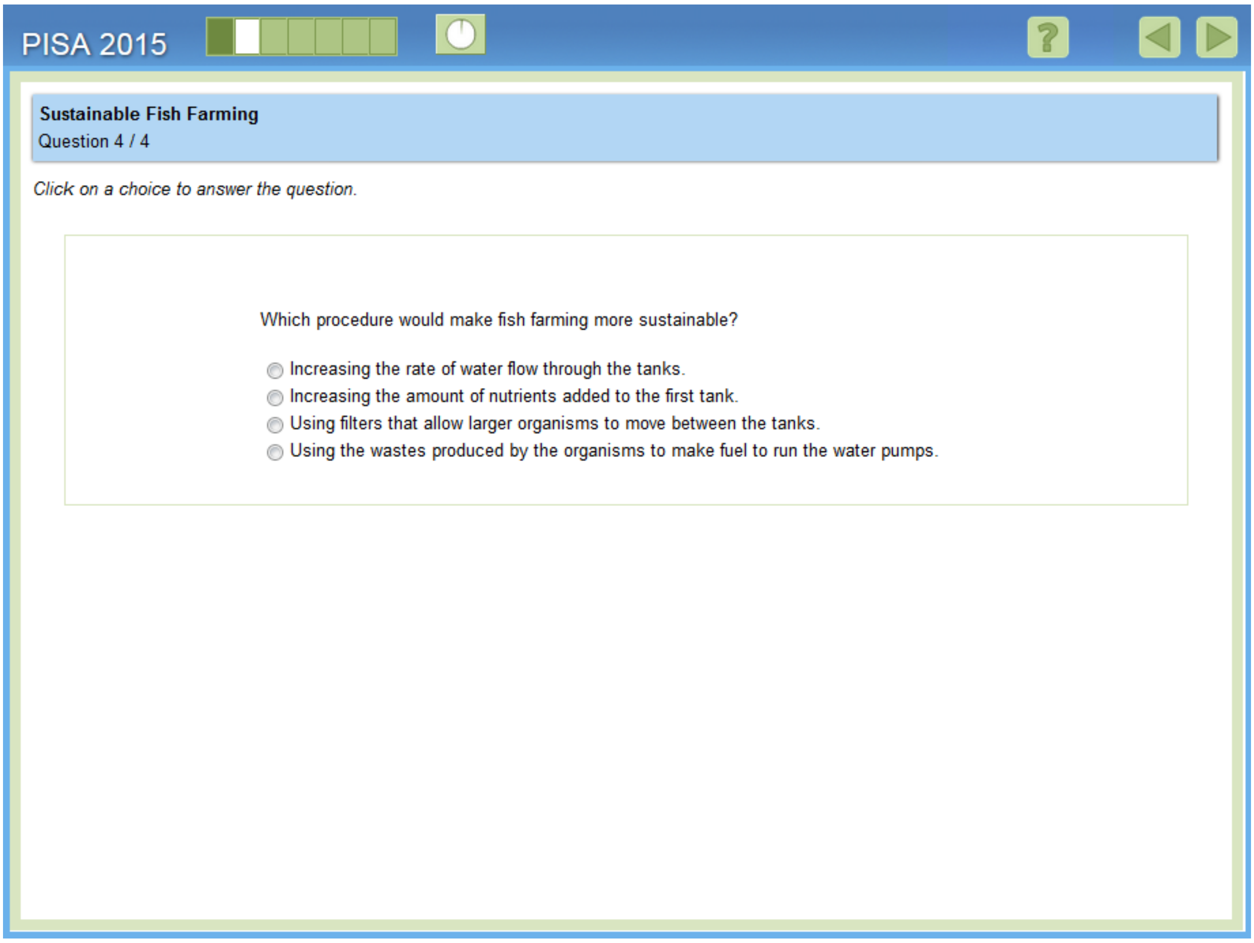
Question Type	Simple Multiple Choice
Competency	Interpret data and evidence scientifically
Knowledge – System	Content – Living
Context	Local/ National – Environmental Quality
Difficulty	457 – Level 2
Question ID	CS601Q02S
Percent Correct	Ireland 74.8%; OECD 65.6%

Scoring

Full Credit: The student selects:

More marsh grass

Sustainable Fish Farming – Question 3



Question Type	Simple Multiple Choice
Competency	Explain phenomena scientifically
Knowledge – System	Content – Physical
Context	Local/ National – Environmental Quality
Difficulty	590 – Level 4
Question ID	CS601Q04S
Percent Correct	Ireland 46.3%; OECD 35.3%

Scoring

***Full credit**:* The student selects:

Using the wastes produced by the organisms to make fuel to run the water pumps

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