Problem Solving in PISA:

The Results of 15-year-olds on the Computer-based Assessment of Problem Solving in PISA 2012

Rachel Perkins and Gerry Shiel

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Preface

The Programme for International Student Assessment (PISA), a project of the OECD, is an international assessment of the skills and knowledge of 15-year-old students in mathematics, reading and science. PISA takes place in three yearly cycles, the first of which was in 2000. In each cycle, one subject area, or domain, becomes the main focus of the assessment and the other domains are assessed as minor domains. In 2012, the fifth cycle of PISA, mathematics was the main domain. As part of this cycle of PISA, students in Ireland also participated in computer-based assessments of mathematics and digital reading (along with students from 31 other countries), and a computer-based assessment of problem solving (along with students in 43 other countries). The results of the computer-based assessment of problem solving are the focus of this report.

Details of the performance of students in Ireland on the other assessments administered as part of PISA 2012 can be found in *Learning for life: The achievements of 15-year-olds in Ireland on mathematics, reading literacy and science in PISA 2012* (Perkins, Shiel, Merriman, Cosgrove & Moran, 2013). The OECD has published a framework for PISA 2012 (2013a) and the initial results from PISA 2012, including the results of the problem-solving assessment, in five volumes (OECD, 2013b-e; OECD, 2014).

This report is divided into four chapters. Chapter 1 provides an introduction to PISA 2012 and an overview of the problem-solving framework, as well as a summary of performance in Ireland on earlier assessments of problem solving. Chapter 2 describes the achievements of students in Ireland on the assessment of problem solving while Chapter 3 examines student factors that are associated with performance on problem solving. Conclusions drawn from the main findings for Ireland are presented in Chapter 4.

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Executive Summary

In 2012, the Programme for International Student Assessment (PISA) was administered in 65 countries/economies, including all 34 member states of the Organisation for Economic Co-operation and Development (OECD). All participating countries administered print-based assessments of mathematics, reading literacy and science. In subsets of countries, including Ireland, subsamples of students also completed computer-based assessments of mathematics, digital reading and problem solving. The results from the print assessments of mathematics, reading and science and the computer-based assessments of mathematics and digital reading from PISA 2012 have already been released in four volumes by the OECD (OECD, 2013b, c, d, e), while the results for Ireland are described in Perkins et al. (2013). Volume five of the PISA 2012 results (OECD, 2014) describes the results of the computer-based assessment of problem solving for all 44 participating countries and the current report presents the results for Ireland on this assessment.

Ireland's mean problem-solving score is 498.3, which does not differ significantly from the average score across the 28 participating OECD countries (500.1). In Ireland, the score of lower-achieving students (i.e., those at the 10th percentile) is similar to the corresponding 28-country OECD average score (378.2 and 375.0, respectively). The score of higher-achieving students in Ireland (i.e. those scoring at the 90th percentile) is also not significantly different from the corresponding 28-country OECD average (614.8 and 619.7, respectively). The percentage of students who have problem-solving scores below Level 2 in Ireland (20.3%) is very close to the 28 OECD country average (21.4%), likewise the percentage of students in Ireland who achieve scores at Level 5 or above is similar to the 28-country OECD average (9.4% and 11.4%, respectively). In Ireland, male and female student do not differ significantly in terms of their problem-solving performance (500.9 and 495.7, respectively). Both male and female students in Ireland have similar mean scores to the corresponding 28-country OECD average scores (503.4 for males and 496.7 for females). The size of the gender difference in Ireland (5.3 points) is also similar to the 28-country OECD average (6.6 points), although, unlike Ireland, the OECD average gender difference is statistically significant.

Students in Ireland perform less well (by over 18 points) on the computer-based assessment of problem solving than would be predicted on the basis of their performance on the print assessments of mathematics, reading and science. Their problem-solving performance is just under 10 points lower than expected on the basis of their performance on the computer-based assessments of mathematics and reading. This indicates that the effect of computer delivery on performance in Ireland is about nine points. Students in Ireland who use a computer at home (97% of students) significantly outperform those who do not on the assessment of problem solving (3% of students), by 30.6 points. However, this difference decreases to 11.2 points and is no longer significant when socio-economic status is accounted for. On the other hand, there is no significant difference between students who have access to and use a desktop, laptop or tablet at school and those who do not in terms of their problem-solving performance, even when socio-economic differences are accounted for.

In Ireland, performance on problem-solving items described as interactive was stronger than expected, given the performance of Irish students on static items (interactive items were found to be slightly harder than static items on average across OECD countries). In terms of performance on tasks involving different types of problem-solving processes, students in Ireland are as likely to be successful on the knowledge-acquisition tasks (i.e. 'exploring and understanding' and 'representing and formulating' tasks) as students on average across the 28 participating OECD countries. Students in Ireland are significantly less likely to be successful on knowledge-utilisation tasks (i.e. 'planning and executing' tasks) compared to the 28-country OECD average, while they are significantly more likely to be successful on the 'monitoring and reflecting' tasks. Female students in Ireland perform at similar levels to male students on tasks measuring each of the problem-solving processes.

In Ireland, schools differ more in terms of their problem-solving performance than their print mathematics, reading or science performance, indicating that the influence of school is greater for problem-solving than for other domains. The amount of between-school variation in problem-solving performance that is explained by the socio-economic composition of schools in Ireland is 10%, but this reduces to 0.1% when mathematics achievement is accounted for. This suggests that socio-economic disparities in problem-solving performance reflect a general academic disadvantage rather than a specific disadvantage in problem solving.

Students with an immigrant background in Ireland perform significantly less well on the assessment of problem solving than native students (by 13.2 points). When compared to students with similar mathematics, reading and science performance, immigrant students in Ireland perform less well in problem solving (-10.7 points), indicating that these students have a specific difficultly with the skills uniquely measured by the computer-based assessment of problem solving. However, it is not clear to what extent this difficulty relates to problem-solving proficiency, the mode of delivery of the assessment or some combination of the two. On the other hand, students in Transition Year perform significantly above their expected level (+ 5 points), given their performance in mathematics, reading and science, possibly due to greater engagement with computers or greater opportunity to develop problem-solving skills in Transition Year.

Students in Ireland have significantly higher levels of reported perseverance on problems (0.14) compared to the 28-country OECD average (0.00), but do not differ in terms of openness to problem solving (-0.02 and 0.00, respectively). The relationship between openness to problem solving and performance is stronger among higher-achieving students than lower-achieving students. A similar pattern is evident for perseverance.

1. Introduction

The OECD's Programme for International Student Assessment (PISA) is an international survey of the skills and knowledge of 15-year-old students in three areas of literacy (mathematics, reading and science). The survey has been conducted every three years since 2000 and 65 countries/economies (including all 34 OECD member states) participated in the assessment in 2012.

The latest results from this study relate to a new computer-based assessment of problem solving. In 2012, problem solving was included as an optional assessment and 44 countries/economies, including Ireland and 27 other OECD countries, participated in the assessment (Table 1.1). In each of these countries/economies, a randomly selected subset of students sampled for the print assessment was also selected to participate in the computer-based assessment. In Ireland, 1,303 students in 183 schools participated in the computer-based assessment of problem solving,[1] which was administered in schools after the print assessment,[2] usually on the afternoon of the same day.

Table 1.1. Countries/economies that participated in the problem-solving assessment

Australia	**Czech Republic**	**Japan**	Shanghai-China
Austria	**Denmark**	**Korea**	Singapore
Belgium	**Estonia**	Macao-China	**Slovak Republic**
Brazil	**Finland**	Malaysia	**Slovenia**
Bulgaria	**France**	Montenegro	**Spain**
Canada	**Germany**	**Netherlands**	**Sweden**
Chile	Hong Kong-China	**Norway**	**Turkey**
Chinese Taipei	**Hungary**	**Poland**	United Arab Emirates
Colombia	**Ireland**	**Portugal**	**United Kingdom**
Croatia	**Israel**	Russian Federation	**United States**
Cyprus	**Italy**	Serbia	Uruguay

Note. OECD member states are in bold

1.1. Problem-solving Framework

PISA 2012 is the second cycle of PISA that has included individual problem solving as an additional assessment domain. The assessment of problem solving has been significantly revised since it was last administered, in PISA 2003. Most notably, the assessment has moved to a computer-based platform, making possible the inclusion of more complex and authentic problems that require an interaction between the test-taker and the problem. Further, the test software allows real-time capture of data on the nature of these interactions, i.e., on the problem-solving process.

An associated change in the problem-solving framework for PISA 2012 relates to the scope of the assessment. While PISA 2003 tested cross-disciplinary problem solving, PISA 2012 expressly excludes problems requiring expert knowledge of substantive areas for their solution. The assessment framework (OECD, 2013a) is based on 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

[1] In Ireland and 31 other countries, the computer-based assessment of problem solving was administered alongside the computer-based assessment of reading and mathematics. In total, 2,396 students participated in the computer-based assessment in Ireland. Twenty-four forms of the computer-based assessment (including a mixture of questions across the three domains) were randomly assigned to participating students, with each student presented with just one form of the assessment. Each form of the assessment included questions from a maximum of two domains; therefore, not all students who participated in the computer-based assessment completed problem-solving questions.

[2] In Ireland, 5, 016 students completed the print assessment of mathematics, reading and science.

knowledge. It was envisaged that the interactivity afforded by the computer-based mode of delivery would, to some extent, allow for the assessment of these more general cognitive capacities that are thought to underlie problem-solving competency (OECD, 2013a).

For the purposes of PISA 2012, problem-solving competency is defined as

> "an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen" (OECD, 2013a, p122).

This definition recognises that problem solving involves not only cognition, but also motivational and affective factors (Funke, 2010). The PISA 2012 problem-solving framework is composed of three main elements: the problem context, the nature of the problem situation and the problem-solving processes.

1.1.1. Problem Context

The contexts in which problems are set are classified according to two dimensions: the setting (i.e., whether it involves technology or not) and the focus (personal or social).

Problems set in a *technology* context have the functionality of a technological device as their basis, e.g., mobile phones, remote controls for appliances, ticket vending machines. Problems that occur in other settings are classified as having *non-technology* contexts, e.g., route planning, task scheduling, decision-making.

Personal contexts include those relating to the self, family and peer groups, while *social* contexts refer to the community or society in general.

1.1.2. Nature of the Problem Situation

The nature of the problem situation is determined by whether the information provided to the problem solver at the outset is complete (a static problem situation) or whether it is necessary to explore the problem situation to uncover additional relevant information (an interactive problem situation). Examples of interactive problem situations include encountering technological devices (e.g., mobile phones or ticket vending machines) for the first time.

1.1.3. Problem-solving Processes

The assessment framework specifies four processes involved in problem solving:

- **Exploring and understanding,** which involves building mental representations of each of the pieces of information presented in the problem. This includes exploring the problem situation (observing it, interacting with it, searching for information and finding limitations and obstacles); and understanding given information and information discovered while interacting with the problem situation; demonstrating understanding of relevant concepts.
- **Representing and formulating**, which refers to building a mental model of the problem situation (i.e., a model of the problem or situation). To do this, relevant information must be selected, mentally organised and integrated with relevant prior knowledge. This may involve representing the problem through tabular, graphical, symbolic or verbal representations, and shifting between these representational formats; formulating hypotheses by identifying

the relevant factors in the problem and their interrelationships; and organising and critically evaluating information.

- **Planning and executing**, which consists of goal setting (including clarifying the overall goal, and setting sub-goals, where necessary); devising a plan or strategy to reach the goal (including the steps to be undertaken); and executing, which consists of carrying out the plan.
- **Monitoring and reflecting**, which includes monitoring progress towards the goal at each stage (including checking intermediate and final results, detecting unexpected events, and taking remedial action when required); and reflecting on solutions from different perspectives, critically evaluating assumptions and alternative solutions, identifying the need for additional information or clarification and communicating progress in a suitable manner.

Engaging in these problem-solving processes requires the use of reasoning skills. Examples of reasoning skills that underlie problem-solving processes include deductive, inductive, quantitative, correlational, analogical, combinatorial and multidimensional reasoning (OECD, 2013a). A broad mix of reasoning skills is sampled across assessment items, as the complexity of the problem and types of reasoning involved affects item difficulty.

1.1.4. PISA 2012 Problem-solving Test Characteristics

The computer-based assessment of problem solving consists of 42 items distributed over 16 units, the characteristics of which are derived from the main elements of the framework. Table 1.2 describes the problem-solving items in terms of context (setting and focus), nature of the problem situation and the main problem-solving process involved. There is an even split of items presented in technology and non-technology settings. Just over half of items are presented in a personal setting, with the remainder presented in a social setting. Almost two-thirds of items are considered to be interactive, with just over a third considered to be static. Almost a quarter of items are 'exploring and understanding' tasks, while just under a fifth are 'representing and formulating' tasks. Approximately 38% of items mainly involve 'planning and executing' and the remaining 17% are classified as 'monitoring and reflecting' tasks. Examples of items presented to students in the assessment of problem solving that illustrate these processes are given in Appendix A.

Table 1.2: Distribution of the 2012 problem-solving items by context (setting and focus), nature of problem situation and problem-solving process involved

Context (setting)	%	Context (focus)	%	Nature of problem situation	%	Problem-solving process	%
Technology	50.0	Social	45.2	Static	35.7	Exploring & understanding	23.8
Non-technology	50.0	Personal	54.8	Interactive	64.3	Representing & formulating	21.4
						Planning & executing	38.1
						Monitoring & reflecting	16.7

1.2. Outcomes from Previous Assessments of Problem Solving

As mentioned previously, problem solving was also assessed as an additional domain in PISA 2003, although in print (paper-based) format and thus did not include interactive items. Ireland's mean problem-solving score in 2003 was 499, which did not differ significantly from the OECD average of 500 (OECD, 2004). The overall performance of students in Ireland was not significantly different from that of students in Sweden, Austria, Hungary, the Slovak Republic and Norway. Problem-solving performance was also described in terms of four proficiency levels: Levels 3, 2, 1 and below Level 1. The proportions of students in Ireland scoring at the highest (Level 3) and lowest (below Level 1) proficiency levels were considerably lower than the corresponding OECD averages, indicating a narrower spread of achievement in Ireland. Just over 12% of students in Ireland achieved a score at Level 3, compared to 18% on average across OECD countries, while 13% of students in Ireland and 17% of students across the OECD scored below Level 1.

The difference between male and female students in Ireland on the overall problem-solving scale was very small and not significant, with males outperforming females by just half a point (OECD, 2004). There was also very little difference between the proportion of male and female students in Ireland at Level 3 (about 12% for both genders) or below Level 1 (about 13% for both genders). On average across OECD countries, females outperformed males by two points; however this difference was not statistically significant. In Ireland, strong positive correlations were found between performance on problem solving and mathematics (r=.90), reading (r=.87) and science (r=.85).

The OECD's Programme for the International Assessment of Adult Competencies (PIAAC), in which Ireland participated in 2012, included an assessment of problem-solving proficiency in technology-rich environments. This assessment measured respondents' ability to use computer applications such as email, spread sheets or internet browsers to do various tasks. In Ireland, 42% of respondents scored at or below Level 1 on this assessment, which is the same as the study average (OECD, 2013f). On the other hand, 25% of adults in Ireland obtained scores at Levels 2 and 3 (the highest levels) compared to the study average of 34%.[3] Males in Ireland significantly outperformed females on this assessment (280 and 274, respectively). There were also significantly more males than females performing at Levels 2 and 3 in Ireland (41.0% and 34.4%, respectively).

The results of PISA, and to some extent PIACC, indicate that Ireland is performing at average levels in terms of problem-solving proficiency, but that there are fewer respondents reaching the higher levels of proficiency in Ireland compared to other countries.

1.3. Summary of Results from Other Domains in PISA 2012

Of the students that were selected to participate in PISA 212 in Ireland, all were selected to take part in the print assessment of mathematics, reading and science and a subset were also selected to participate in the computer-based assessment of mathematics, reading and problem solving. The computer-based assessment was administered after the print assessment but on same day.

The results from the print assessments of mathematics, reading and science and the computer-based assessments of mathematics and reading from PISA 2012 have already been released (OECD, 2013b, c, d, e; Perkins et al., 2013). Ireland achieved mean scores in print mathematics, reading and science (502, 523 and 522, respectively) that were above the corresponding OECD averages (494, 497 and 501, respectively). The performance of students in Ireland on print mathematics and reading is significantly higher in 2012 than in 2009, but does not differ significantly from the performance of Irish students in earlier PISA cycles. On the other hand, the mean science score of students in Ireland in 2012 is significantly higher than in all previous cycles that can be compared for science.

Ireland's performance on the assessment of digital reading was also above the OECD average in 2012 (520 and 497, respectively) while performance on the computer-based assessment of

[3] The remaining 32.8% did not attempt the problem solving test at all, due to either opting out of the computer-based assessment, failing the basic computer skills test, no computer experience or missingness.

mathematics in Ireland was not significantly different from the OECD average (493 and 497, respectively). Digital reading was also assessed in 2009, and the mean score of students in Ireland on this assessment saw a significant improvement between 2009 and 2012.

In 2012, male students in Ireland significantly outperformed female students on both the print and computer-based assessments of mathematics, while females significantly outperformed males on the assessments of print and digital reading. The difference between male and female students on the science assessment was not significant. Both male and female students in Ireland have seen significant improvements in their print reading, print mathematics, science and digital reading scores in 2012 compared to 2009.

Ireland has fewer lower-achieving students than the OECD average for each domain, although only slightly so for computer-based mathematics. Ireland also has fewer students reaching the highest levels on the print and computer-based mathematics assessment, when compared to the corresponding OECD averages. On the other hand, the proportions of higher-achieving students on the reading (print and digital) and science assessments are higher in Ireland than on average across OECD countries. Across all domains, the proportion of lower-achieving students has decreased and the proportion of higher-achieving students has increased in Ireland since 2009.

Inset 1.1. How to Interpret the Analyses in this Report

OECD average

Throughout this 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. Unless otherwise stated, the OECD average refers to the average of the 28 OECD countries that participated in the computer-based assessment of problem solving. Where references are made to 'OECD' in tables and figures, this always refers to the OECD average. Also in this report, 'mean' and 'average' are used interchangeably.

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 we would expect the population estimate to fall 95% of the time, if we were to use many repeated samples. 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. 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 these scores differ significantly from one another (i.e. $p<.05$), the reader can infer that the difference is *statistically* significant.

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. In PISA 2012, Ireland achieved a mean problem-solving score of 498 and the standard deviation was 93. Therefore, 68% of students in Ireland are estimated to have obtained an achievement score between 405 and 591 (498±93*1), while 95% of students are estimated to have obtained achievement scores between 312 and 684 (498±93*2).

Proficiency levels

In PISA, student performance and the level of difficulty of assessment items are placed on a single scale for each domain assessed. Using this approach 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 2012, six proficiency levels are described for the computer-based assessment of problem solving. Level 2 is considered the basic level of proficiency needed to participate effectively and productively in society and in future learning (OECD, 2014). 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 socio-economic status and reading achievement). However, a correlation does not imply a causal relationship. The value of a correlation (i.e. the *r* value) can range from -1 to +1. A value of 0 indicates that there is no relationship between variables, while the closer a value is to ±1, the stronger the relationship. 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.

2. Performance on Problem Solving

This chapter provides an overview of the performance of students in Ireland on the assessment of problem solving administered as part of PISA 2012. Results are described in terms of overall performance as well as performance at key benchmarks and proficiency levels. Gender differences in performance are also presented. Variation in performance, the effect of computer delivery on performance and performance on different types of problem-solving tasks and are also examined. Finally, how achievement on problem solving compares to achievement on mathematics, reading and science is described.

2.1. Overall Performance on Problem Solving

Students in Ireland have a mean score of 498.3 on the assessment of problem solving. This does not differ significantly from the average score of the 28 OECD countries (500.1) that participated in the assessment (Table 2.1). Ireland's score is ranked 17th of the 28 participating OECD countries, and 22nd of all 44 participating countries/economies. Applying a 95% confidence interval, which takes account of measurement and sampling error, Ireland's true rank is between 15th and 19th among OECD countries and between 20th and 24th among all participating countries/economies.

Eighteen countries/economies, including thirteen OECD countries, have mean problem-solving scores that are significantly above Ireland's. Six countries (the United States, Austria, Norway, Denmark, Portugal and Sweden) achieve mean scores that do not differ significantly from the mean score for Ireland. The remaining 19 countries, including eight OECD countries, perform significantly less well than Ireland on the assessment of problem solving.

The standard deviation for Ireland (93.1) is similar to the standard deviation across the 28 participating OECD countries (95.9), indicating that there is a similar spread of scores in Ireland and on average across the 28 participating OECD countries. Also, the inter-decile range (i.e., the score at the 90th percentile minus the score at the 10th percentile) for Ireland (236.7 points) is not significantly different from the corresponding 28-OECD country average (244.7 points). As with many participating countries, the spread of achievement in Ireland is somewhat wider at the lower end of the performance scale (i.e. between the 50th and 10th percentiles) than at the higher end of the scale (i.e. between the 50th and 90th percentiles). In Ireland, the range at the lower end of the scale is 123 points, compared to 113 points at the higher end of the scale, and both are similar to the corresponding 28-country OECD averages (129 points at the lower end of the scale and 115 points at the higher end of the scale).

Table 2.1. Mean country/economy scores, standard deviations and standard errors (SE) for the problem solving scale and positions relative to the 28-country OECD and Irish means, for all participating countries/economies

	Mean	SE	SD	SE	IRL
Singapore	562.4	(1.22)	95.0	(0.96)	▲
Korea	561.1	(4.32)	91.2	(1.76)	▲
Japan	552.2	(3.14)	85.2	(1.91)	▲
Macao-China	540.5	(1.02)	79.2	(0.81)	▲
Hong Kong-China	539.6	(3.91)	91.7	(2.20)	▲
Shanghai-China	536.4	(3.29)	89.9	(2.25)	▲
Chinese Taipei	534.4	(2.88)	90.9	(1.93)	▲
Canada	525.7	(2.40)	100.3	(1.66)	▲
Australia	523.1	(1.92)	97.4	(1.02)	▲
Finland	522.8	(2.27)	93.0	(1.21)	▲
United Kingdom	516.8	(4.17)	96.7	(2.37)	▲
Estonia	515.0	(2.51)	87.5	(1.52)	▲
France	511.0	(3.44)	96.2	(4.09)	▲
Netherlands	510.7	(4.40)	98.9	(2.99)	▲
Italy	509.6	(4.04)	90.7	(2.08)	▲
Czech Republic	509.0	(3.12)	95.2	(2.04)	▲
Germany	508.7	(3.62)	98.5	(2.47)	▲
United States	507.9	(3.90)	92.8	(2.26)	O
Belgium	507.7	(2.48)	106.5	(1.82)	▲
Austria	506.4	(3.58)	93.8	(2.93)	O
Norway	503.3	(3.26)	103.0	(1.92)	O
Ireland	498.3	(3.18)	93.1	(1.95)	
Denmark	497.1	(2.92)	92.3	(1.92)	O
Portugal	494.4	(3.56)	87.8	(1.60)	O
Sweden	490.7	(2.92)	96.2	(1.81)	O
Russian Federation	489.1	(3.43)	87.9	(2.01)	▼
Slovak Republic	483.3	(3.57)	98.0	(2.75)	▼
Poland	480.8	(4.45)	96.5	(3.35)	▼
Spain	476.8	(4.10)	104.4	(2.86)	▼
Slovenia	475.8	(1.52)	97.1	(1.29)	▼
Serbia	473.4	(3.10)	89.1	(1.91)	▼
Croatia	466.3	(3.86)	92.0	(1.96)	▼
Hungary	459.0	(4.01)	104.4	(2.71)	▼
Turkey	454.5	(4.02)	79.0	(2.21)	▼
Israel	454.0	(5.47)	123.4	(3.20)	▼
Chile	447.9	(3.70)	85.9	(1.68)	▼
Cyprus	444.9	(1.45)	98.9	(0.99)	▼
Brazil	428.5	(4.71)	91.8	(2.37)	▼
Malaysia	422.5	(3.52)	83.6	(1.98)	▼
United Arab Emirates	411.2	(2.76)	105.5	(1.82)	▼
Montenegro	406.7	(1.16)	91.6	(1.10)	▼
Uruguay	403.4	(3.47)	97.2	(2.00)	▼
Bulgaria	401.7	(5.10)	106.5	(3.54)	▼
Colombia	399.2	(3.54)	91.6	(1.96)	▼
OECD Average	500.1	(0.67)	95.9	(0.43)	

[dark grey]	Significantly above OECD average	▲	Significantly higher than Ireland
[white]	At OECD average	O	Not significantly different from Ireland
[light grey]	Significantly below OECD average	▼	Significantly lower than Ireland

Source: OECD (2014) Figure V.2.3.

2.2. Performance at Key Benchmarks on the Problem Solving Scale

In Ireland, the score of students at the 10th percentile is 378.2, which is similar to the corresponding 28-country OECD average score (375.0). The performance of lower-performing students (i.e. those at the 10th percentile) in Ireland is over 58 points lower than the corresponding score in Singapore (436.3), the highest performing country, and is also significantly lower than in Canada (398.3), Australia (395.7) and Finland (400.7). Although the United Kingdom, France, the Netherlands, the Czech Republic and Germany have overall mean scores that are significantly higher than Ireland's, the scores of students at the 10th percentile in these countries' (390.8, 387.1, 377.7, 383.5 and 377.0, respectively) do not differ significantly from the corresponding score of Irish students, indicating a relatively strong performance among lower-achieving students in Ireland. Lower-performing students in Ireland significantly outperformed their counterparts in Sweden (364.7) and Poland (358.4).

In Ireland, the performance of students scoring at the 90th percentile is also similar to the corresponding average across the 28 participating OECD countries (614.8 and 619.7, respectively), but is well below the performance of those at the 90th percentile in Singapore (680.7). The score of students at the 90th percentile in Ireland is also significantly lower than the corresponding scores of students in the United Kingdom (635.8), France (626.0), the Netherlands (633.3), the Czech Republic (626.4) and Germany (629.1), countries whose performance at the 10th percentile is not significantly different from Ireland's.

2.3. Performance on Problem Solving Proficiency Levels

Student performance in problem solving can also be described in terms of proficiency levels, which group students at various points on the achievement scale such that the skills and competencies of students of various ability levels can be described. Table 2.2 presents a description of the types of tasks that students at each of six proficiency levels are likely to succeed on. Level 6 is the highest levels and students performing at this level are capable of successfully completing the most difficult PISA tasks. Level 2, on the other hand, is considered by the OECD as the baseline level of problem-solving proficiency at which students begin to demonstrate the skills that will allow them to participate effectively and productively in 21st century societies (OECD, 2014).

The percentage of students who have problem-solving scores below Level 2 in Ireland (20.3%) is similar to the 28 OECD country average (21.4%). The percentage of lower-achieving students (i.e. below Level 2) in Ireland is somewhat greater than in Canada (14.7%), Australia (15.5%), the United Kingdom (16.4%) and France (16.5%) but is not significantly different from the percentage in the United States (18.2%), Austria (18.4%) and Germany (19.2%). There are considerably fewer lower-achieving students in many of the Asian countries that participate in PISA, such as Korea (6.9%), Japan (7.1%), Macao-China (7.5%) and Singapore (8.0%).

Slightly fewer students in Ireland achieve scores at Level 5 or above compared to the 28-country OECD average (9.4% and 11.4%, respectively). The percentage of higher-achieving students (i.e. at Level 5 or above) in Ireland is similar to the percentages found in Sweden (8.8%) and Denmark (8.7%), but is considerably lower than in Canada (17.5%), Australia (16.7%) and the United Kingdom (14.3%). In each of the three highest-performing countries, the proportion of students performing at Level 5 or above is greater than 20%: Singapore (29.3%), Korea (27.6%) and Japan (22.3%).

Table 2.2. Descriptions of the six levels of proficiency on the overall computer-based problem-solving scale and percentages of students achieving each level, in Ireland and on average across OECD countries

Level *(Cut-point)*	Students at this level are capable of:	OECD		Ireland	
		%	SE	%	SE
6 *(683 and above)*	*Developing complete, coherent mental models of diverse problem scenarios, enabling them to solve complex problems efficiently*. They can explore a scenario in a highly strategic manner to understand all information pertaining to the problem. The information may be presented in different formats, requiring interpretation and integration of related parts. When confronted with very complex devices, such as home appliances that work in an unusual or unexpected manner, they quickly learn how to control the devices to achieve a goal in an optimal way. Level 6 problem-solvers can set up general hypotheses about a system and thoroughly test them. They can follow a premise through to a logical conclusion or recognise when there is not enough information available to reach one. In order to reach a solution, these highly proficient problem-solvers can create complex, flexible, multi-step plans that they continually monitor during execution. Where necessary, they modify their strategies, taking all constraints into account, both explicit and implicit.	2.5	(0.1)	2.1	(0.3)
5 *(618 to less than 683)*	*Systematically exploring a complex problem scenario to gain an understanding of how relevant information is structured*. When faced with unfamiliar, moderately complex devices, such as vending machines or home appliances, they respond quickly to feedback in order to control the device. In order to reach a solution, Level 5 problem-solvers think ahead to find the best strategy that addresses all the given constraints. They can immediately adjust their plans or backtrack when they detect unexpected difficulties or when they make mistakes that take them off course.	8.9	(0.1)	7.3	(0.6)
4 *(553 to less than 618)*	*Exploring a moderately complex problem scenario in a focused way.* They grasp the links among the components of the scenario that are required to solve the problem. They can control moderately complex digital devices, such as unfamiliar vending machines or home appliances, but they don't always do so efficiently. These students can plan a few steps ahead and monitor the progress of their plans. They are usually able to adjust these plans or reformulate a goal in light of feedback. They can systematically try out different possibilities and check whether multiple conditions have been satisfied. They can form a hypothesis about why a system is malfunctioning, and describe how to test it.	19.6	(0.2)	18.8	(0.8)
3 *(488 to less than 553)*	*Handling information presented in several different formats.* They can explore a problem scenario and infer simple relationships among its components. They can control simple digital devices, but have trouble with more complex devices. Problem-solvers at Level 3 can fully deal with one condition, for example, by generating several solutions and checking to see whether these satisfy the condition. When there are multiple conditions or inter-related features, they can hold one variable constant to see the effect of change on the other variables. They can devise and execute tests to confirm or refute a given hypothesis. They understand the need to plan ahead and monitor progress, and are able to try a different option if necessary.	25.6	(0.2)	27.8	(0.9)
2 *(423 to less than 488)*	*Exploring an unfamiliar problem scenario and understanding a small part of it*. They try, but only partially succeed, to understand and control digital devices with unfamiliar controls, such as home appliances and vending machines. Level 2 problem-solvers can test a simple hypothesis that is given to them and can solve a problem that has a single, specific constraint. They can plan and carry out one step at a time to achieve a sub-goal, and have some capacity to monitor overall progress towards a solution.	22.0	(0.2)	23.8	(0.8)
1 *(358 to less than 423)*	*Exploring a problem scenario only in a limited way, though often only when very similar situations have been encountered before.* Based on their observations of familiar scenarios, these students are able only to partially describe the behaviour of a simple, everyday device. In general, students at Level 1 can solve straightforward problems provided there is only a simple condition to be satisfied and there are only one or two steps to be performed to reach the goal. Level 1 students tend not to be able to plan ahead or set sub-goals.	13.2	(0.2)	13.3	(0.9)
Below Level 1 *(below 358)*	There were insufficient items to fully describe performance that falls below Level 1 on the problem-solving scale.	8.2	(0.2)	7.0	(0.8)

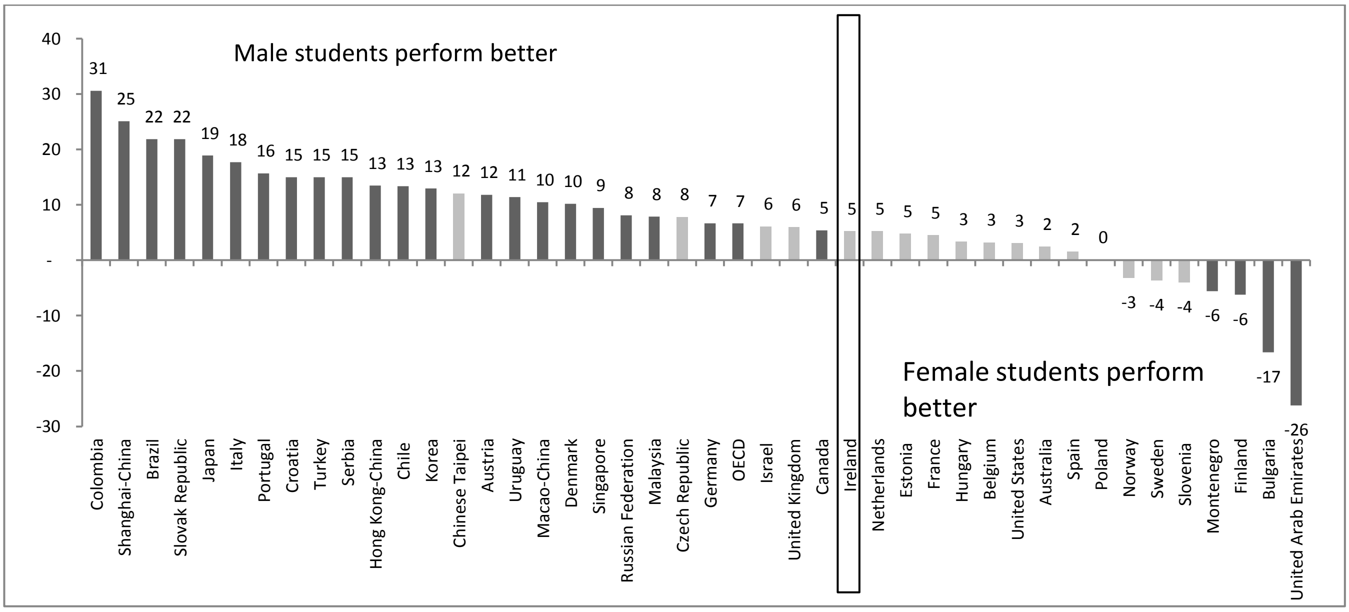
Source: OECD (2014) Figure V.2.5.

2.4. Gender Differences in Problem Solving

Male students in Ireland have a slightly higher mean score than female students (500.9 and 495.7, respectively), although the difference is not statistically significant. Both male and female students in Ireland have similar mean scores to the corresponding 28-country OECD average scores (503.4 for males and 496.7 for females). The size of the gender difference in Ireland (5.3 points) is also similar to the 28-coutry OECD average (6.6 points), although the OECD average gender difference is significant.

In 35 out of 44 participating countries, male students have higher mean scores than female students, although the differences are significant in only 22 countries. In four countries (Montenegro, Finland, Bulgaria and the United Arab Emirates), female students significantly outperform male students (Figure 2.1).

Figure 2.1. Gender differences for all participating countries and the average across the 28 participating OECD countries



Note. Significant differences are highlighted in dark grey. Source: OECD (2014) Table V.4.7.

In Ireland, there are no significant differences between the performance of male and female students at the 10th percentile or at the 90th percentile (Table 2.3). The scores of males and females at the 10th and 90th percentiles in Ireland are similar to the corresponding OECD averages.

Table 2.3. Scores of students at the 10th and 90th percentiles, for Ireland and the average across the 28 participating OECD countries

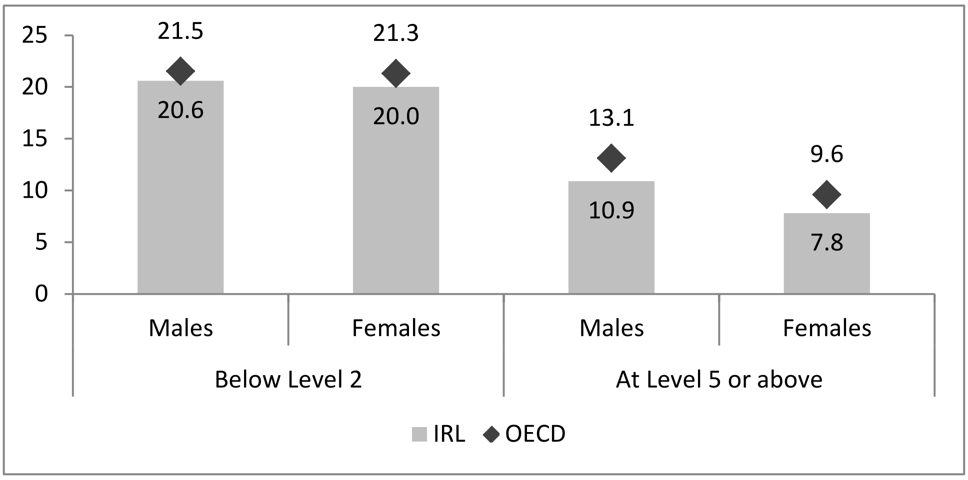
	Ireland				OECD			
	Males		Females		Males		Females	
	Scale score	SE	Scale score	SE	Scale score	SE	Scale score	SE
10th percentile	376.7	(7.94)	380.1	(5.42)	372.3	(1.39)	377.9	(1.23)
90th percentile	622.3	(7.59)	606.9	(4.06)	627.4	(1.02)	610.6	(0.97)

Source: OECD (2014) Table V.4.7

Twenty-one percent of males and 20.0% of females in Ireland perform below Level 2 on the problem solving assessment. The corresponding 28-country OECD average percentages (21.5% for males and 21.3% for females; Figure 2.2) are only slightly higher. Almost 11% of males in Ireland are considered higher-achievers (i.e. performing at Level 5 or above) on the problem-solving assessment, compared to approximately 8% of female students. The proportions of higher achieving males and females in

Ireland are somewhat below the corresponding 28-country OECD averages (13.1% for males and 9.6% for females).

Figure 2.2. Percentages of students performing below Level 2 and at Level 5 or above on the assessment of problem solving, for Ireland and the average across the 28 participating OECD countries



Source: OECD (2014) Table V.2.1

2.5. Differences in Variation Between and Within Schools

The variation in performance within countries can be divided into performance differences between students from the same school (within-school variation) and performance differences between groups of students from different schools (between-school variation). Between-school variation can be interpreted as a measure of 'school effects' and therefore as an indicator of equity within a school system.

In Ireland, the amount of variance in performance attributed to differences between schools is 24.6%, which is the sixth-lowest level of between-school variance among all 44 participating countries (Estonia, Canada, Norway, Sweden and Finland have lower levels of between-school variance). On average across the 28 participating OECD countries, 38.3% of variation in performance is due to differences in student performance between schools.

In Ireland, the between-school difference in performance in problem solving is larger than for mathematics (18.2%), reading (22.5%) and science (18.3%) performance, suggesting that the influence of school is greater for problem solving, although only marginally so when compared to reading performance (OECD, 2014, Table V.2.4). Also, in Ireland, the amount of variance in problem-solving performance that lies between schools is larger than the amount of between-school variance in socio-economic status (20.3%),[4] indicating that schools differ more in terms of their problem-solving performance than their socio-economic composition. This suggests that schools have more of an influence on problem-solving proficiency than family background.

2.6. The Effect of Computer Delivery on Performance

The assessment of problem solving in 2012 was delivered on a computer-based platform. It is possible that the mode of delivery may have had an impact on students' performance on the assessment, perhaps due to different levels of familiarity with using computers or anxiety with using a novel testing mode. The proportion of variation in problem solving that is uniquely explained by

[4] In PISA, socio-economic status is measured using the index of economic, cultural and social status (ESCS).

performance differences in the computer-based assessment, after accounting for differences in the print assessments in the same domains, is a measure of the influence of computer delivery on performance in problem solving within a country.[5] In Ireland, 1.1% of variation in performance in problem solving can be attributed to differences in computer skills, compared to a 28-country OECD average of 4.2%, indicating that students in Ireland are more alike in terms of their ICT skills than on average across the 28 participating OECD countries. However, students in Ireland have lower levels of familiarity with using ICTs at schools and at home for school-related tasks than on average across all 34 OECD countries, suggesting that a lack of familiarity with school-based computer tasks has contributed to lower performance on the computer-based assessments in Ireland (Table 2.4).

Table 2.4. Mean scores of students on the indices of use of ICTs at school, in mathematics lessons and at home for school related tasks, in Ireland and on average across OECD countries

	Use of ICTs at school		Use of ICTs in mathematics lessons		Use of ICTs at home for school-related tasks	
	Mean	SE	Mean	SE	Mean	SE
Ireland	**-0.07**	(0.02)	**-0.15**	(0.02)	**-0.60**	(0.02)
OECD (Ref)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)

Note. Significant differences are highlighted in bold

Ireland's relatively weaker performance in problem solving appears to be compounded by a more general weakness on computer-based assessments. The problem-solving performance of students in Ireland is 18.7 points lower than expected given their performance on the print assessments of mathematics, reading and science, while the average performance across OECD countries is 8.6 points lower than expected.[6] However, Irelands' problem-solving performance is 9.7 points lower and the OECD average performance is 1.3 points lower than expected, when performance on the computer-based assessments of mathematics and reading is accounted for. This indicates that the mode effect (i.e. the effect of computer delivery on performance) in Ireland is -9.0 points, which is about the same as the average across the 28 participating OECD countries (-7.9 points).

2.7. Performance on Different Types of Problem-solving Items

In the PISA problem-solving framework, items are classified according to the nature of the problem and the cognitive processes involved in problem solving. Relative strengths and weaknesses on different types of problem-solving items can be identified by computing the average percentage of correct responses (i.e. the number of correct answers divided by the number of students who were administered the question) at the country level.

With regards to the nature of the problem, a distinction is made between static problems (i.e. where all of the information needed to solve the problem is disclosed at the outset) and interactive problems (i.e. where some of the necessary information is not disclosed at the outset and students can explore the situation to uncover additional relevant information). In Ireland, the percentage of correct responses for static items and interactive items is almost identical (44.4% for static items and 44.6% for interactive items). However, interactive items were found to be slightly harder than static items on average across the 28 participating OECD countries (47.1% of static items were answered

[5] The variation explained by the mode of delivery is measured as the difference between the R^2 of regression of problem solving on mathematics, reading and science and the R^2 of the same regression augmented with computer-based reading and computer-based mathematics.
[6] Relative performance in problem solving is computed as the difference between actual performance and the fitted value from a regression using a second-degree polynomial as regression function (math, math sq., read, read sq., scie, scie sq., mathXread, mathXscie, readXscie) using data from all participating students.

correctly compared to 43.8% of interactive items). Therefore, performance on interactive items was stronger than expected in Ireland. Indeed, Ireland's relative success on interactive items was strongest of all participating countries, given our performance on static items. Other countries with stronger than expected performance on interactive items include Korea (58.9% for static items and 57.7% for interactive items), the United States (46.6% for static items and 45.9% for interactive items), Singapore (59.8% for static items and 57.5% for interactive items), Canada (52.7% for static items and 50.5% for interactive items) and Japan (58.7% for static items and 55.9% for interactive items). Students who excel at interactive tasks are 'open to novelty, tolerate doubt and uncertainty, and dare to use intuitions to initiate a solution' (OECD, 2014, p.80). Female students in Ireland perform at somewhat, although not significantly, weaker levels than males on both static and interactive items.

Each item on the problem-solving assessment is also classified as measuring a particular cognitive process. As noted in Chapter 1, four cognitive processes are described for PISA problem solving, each of which applies to both static and interactive problems: exploring and understanding; representing and formulating; planning and executing; and monitoring and reflecting. Among these processes, a further distinction is made between knowledge-acquisition (i.e. 'exploring and understanding' and 'representing and formulating' tasks) and knowledge utilisation tasks ('planning and executing' tasks). 'Monitoring and reflecting' tasks are considered to combine both knowledge-acquisition and knowledge-utilisations aspect and therefore are not included in this distinction.

After accounting for booklet and country-specific response-format effects, the relative likelihood of students in Ireland's being successful on knowledge-acquisition tasks (1.06 for. 'exploring and understanding' tasks and 0.97 for 'representing and formulating' tasks) is in line with the 28-country OECD average performance (1.00 for both processes). Students in Ireland are less likely to be successful on knowledge-utilisation tasks (i.e. 'planning and executing' tasks) compared to the OECD average (0.91 and 1.00, respectively), but are more likely to be successful on 'monitoring and reflecting' tasks (1.11 and 1.00, respectively). Students who are strong on tasks measuring "exploring and understanding" or "representing and formulating" processes are 'good at generating new knowledge; they can be characterised as quick learners, who are highly inquisitive (questioning their own knowledge, challenging assumptions), generating and experimenting with alternatives, and good at abstract information processing' (OECD, 2014, p.84). Female students in Ireland perform at similar levels to male students on tasks measuring each of the problem-solving processes, although performance is somewhat weaker, although not significantly so, on the 'representing and formulating' tasks. Interestingly, many of the top-performing countries/economies in PISA problem solving are countries with better-than-expected performance on knowledge-acquisition tasks and relatively weaker performance on knowledge-utilisation tasks.

2.8. Performance on Problem Solving Compared to Performance on Mathematics, Reading and Science

While the problem-solving assessment does not measure domain-specific knowledge, some of the generic skills and cognitive processes involved in problem solving may be drawn from other domains. Therefore, it is expected that problem solving achievement would be positively correlated with achievement in other domains assessed by PISA. The correlations[7] between problem-solving

[7] See inset 1.1. on page 6.

performance and performance in other domains in PISA are strong, but slightly smaller than the correlations observed among mathematics, reading and science (Table 2.5), providing some support for the view that problem solving constitutes a separate domain from reading, mathematics and science.

In Ireland, and on average across the 28 participating OECD countries, the strongest correlation is between problem solving and mathematics (r=0.80 for Ireland and r=0.81 for the 28-country OECD average), followed by science (r=0.79 for Ireland and 0.78 for the 28-country OECD average) and reading (r=0.74 for Ireland and 0.75 for the 28-country OECD average).

Table 2.5: Correlations between problem-solving, mathematics, reading and science performance, for Ireland

Correlation between:	Print Mathematics	Print Reading	Science
Problem solving and	0.80	0.74	0.79
Print Mathematics and	-	0.87	0.91
Print Reading and	-	-	0.90

Source: OECD (2014) Table V.2.5

Compared with students in all other participating countries, students in Ireland, and on average across the 28 participating OECD countries, perform less well than expected on problem solving given their relatively strong performance in mathematics, reading and science (-18.4 points for Ireland and -7.5 points for the 28-country OECD average).[8] In Ireland, 63.8% of students perform below the expected level on problem solving given their performance in mathematics, reading and science, compared to 54.7% on average across the 28 participating OECD countries.

In Ireland, both students with strong mathematics skills (i.e. at Level 4 or above) and those with less well-developed mathematics skills (i.e. at Level 3 or below) perform less well on the assessment of problem solving compared to the corresponding students in other countries/economies, although the difference is greater among lower-performing students (-6.9 points among those with strong mathematics skills and -16.7 points among those with poorer mathematics skills). In Ireland, female students score 8.7 points higher on the problem solving assessment than male students with similar mathematics performance, but score 29.2 points lower than males with similar reading performance and just 1.7 points lower than males who perform at similar levels on science.

Analysis of performance across countries on the overall mathematics scale, the mathematics content area subscales (Change & Relationships, Space & Shape, Quantity and Uncertainty & Data) and problem solving does not reveal any notable patterns. However, while both the United Kingdom and the United States have a similar pattern of performance to Ireland on the overall mathematics scale and the mathematics content area subscales, their performance on the assessment of problem solving is higher than Ireland's.

[8] Relative performance on problem solving is computed as the difference between actual performance and the fitted value from a regression using a second-degree polynomial as regression function (math, math sq., read, read sq., scie, scie sq., mathXread, mathXscie, readXscie) using data from students that participated in the computer-based assessments.

3. Factors Associated with Problem-solving Performance

In Chapter 2, two important factors that are associated with problem-solving performance were discussed: gender and performance on the other assessment domains. This chapter examines some other students factors that are related to performance in problem solving, specifically student socio-economic status, immigrant status, grade (year) level and students' self-reported dispositions towards problem solving. How problem-solving performance relates to differences in usage of ICT across students is also presented.

3.1. Problem-solving Performance and Socio-economic Status

Socio-economic status in PISA is measured using the index of Economic, Social and Cultural Status (ESCS), which is derived from six variables including parents' education, parents' occupations, cultural possessions, material possessions, home educational resources and the number of books available in the home. In Ireland, student ESCS is positively correlated with problem-solving performance, although the correlation is weaker than for print and computer-based mathematics, print and digital reading, and science (Table 3.1). The amount of variation in performance explained by ESCS for problem solving (10.2%)[9] is less than for print mathematics (14.6%), computer-based mathematics (11.9%), print reading (15.1%) and science (14.5%) but is about the same as for digital reading (10.9%).[10] The percentage of variation in problem-solving performance explained by ESCS is about the same in Ireland as the average across the 28 participating OECD countries (10.5%).

Table 3.1. Correlations between ESCS and mathematics (print and computer-based), reading (print and digital) and science, in Ireland

Correlation between ESCS and :	*r*	*t*	*p*
Problem solving	.319	18.5	<.001
Print mathematics	.382	15.4	<.001
Print reading	.388	26.2	<.001
Science	.380	23.9	<.001
Computer-based mathematics	.345	19.0	<.001
Digital reading	.330	19.6	<.001

In Ireland, the amount of between-school variation in problem-solving performance that is explained by the socio-economic status is 10.0%,[11] however, when mathematics achievement is also accounted for, the proportion of variance accounted for by socio-economic status reduces to 0.1%,[12] suggesting that socio-economic disparities in problem-solving performance reflect a general academic disadvantage at school level rather than a specific disadvantage in problem solving.

In general, students in Ireland who are considered advantaged (i.e. they have at least one parent working in a skilled occupation) are about one-and-a-half times as likely to be successful on both static and interactive items as students who are considered disadvantaged (i.e. with parents working

[9] Based on a single level bivariate regression of performance on ESCS.

[10] The amount of variation in performance explained by ESCS is computed using the R^2 from the regression coefficient of performance on ESCS.

[11] Based on the R^2 from a regression coefficient of performance on ESCS.

[12] This analysis is based on the residual variation in a model with student performance in mathematics, students ESCS, school average performance in mathematics and school average ESCS. Negative estimates of explained variance values are reported as '0'.

in semi-skilled or elementary occupations)[13] (Table 3.2). A similar pattern emerges for items measuring the four problem-solving processes.

Table 3.2. Relative likelihood of success, in favour of students with at least one parent working in a skilled occupation, on items by problem situation and problem-solving process, in Ireland

Item type	Odds ratio	SE
Static	1.47	(0.12)
Interactive	1.55.	(0.11)
Exploring and understanding	1.66	(0.16)
Representing and formulating	1.57	(0.13)
Planning and executing	1.44	(0.10)
Monitoring and reflecting	1.47	(0.13)

Source: OECD (2014) tables V.4.18a and V.4.18b.

3.2. Problem-solving Performance and Immigrant Status

In Ireland, 10.2%[14] of students have an immigrant background.[15] These students achieve a mean problem-solving score that is significantly lower than the score for native students (487.9 and 501.2, respectively). The mean score of native students in Ireland does not differ significantly from the 28-country OECD average (504.9), while the mean score of students with an immigrant background is significantly higher than the corresponding 28-country OECD average score (469.7). After accounting for ESCS, the difference between native students and students with an immigrant background in Ireland increases slightly from 13.2 to 14.6 points in favour of native students, but is still considerably smaller than the average difference between native and immigrant students across the 28-participating OECD countries (31.9 points in favour of native students, or 21.9 points when ESCS is taken into account).

In Ireland, the score point difference between native students and those with an immigrant background is considerably larger for problem solving (13.2 points) than for print and computer-based mathematics (3.0 and 0.8 points, respectively), and science (2.3 points), but is similar to the differences for print and digital reading (11.4 and 11.3 points, respectively). When compared to students with similar mathematics, reading and science performance , immigrant students in Ireland perform less well in problem solving (-10.7 points), suggesting that these students have a specific difficultly with the skills uniquely measured by the computer-based assessment of problem solving. These students may have specific difficulties with problem-solving skills, language proficiency, the computer-based format of the assessment, or some combination of these.

[13] Unlike ESCS, disadvantage/advantage is measured using one variable The OECD classifies students with at least one parent working in a skilled profession (i.e. managers, professionals, technicians and associate professionals) as advantaged and those whose parents work in semi-skilled or elementary professions as disadvantaged. In Ireland, 55.7% of students have at least one parent working in a skilled profession and 40.8% work in a semi-skilled or elementary profession (3.5% of students had missing data on this variable).

[14] When language and immigrant status are examined together the percentage of immigrant students in Ireland (i.e. both immigrant students who speak English or Irish as their first language and those who speak another language) reduces from 10.2% to 9.6%, due to missing data. For the same reason, mean problem-solving scores are somewhat different when immigrant students are split by language status.

[15] In PISA, students are categorised as 'native' if they were born in the country where they took the test or had at least one parent born in the country, and as 'immigrant' if the student and both parents were born in another country, or if both parents were born in another country but the student was born in the country in which the PISA test was taken.

3.3. Problem-solving Performance and Grade Level

PISA is aimed at an age-based sample (i.e. 15-year-olds); therefore participants come from across a number of grade (year) levels. In Ireland, the majority of participating students are in Third Year (60.5%), 24.3% are in Transition Year, 13.3% are in Fifth Year and the remaining 1.9% is in the First and Second Years.[16] The pattern of results for across grade levels is the same for problem solving as it is for the other domains, i.e., students in Transition Year obtain the highest mean score, which is significantly higher than the mean score of students in Third Year. The mean score of students in Third Year does not differ significantly from the mean score of students in Fifth Year or First/Second Years. Students in Transition also have a mean ESCS score[17] that is significantly higher than the mean ESCS for Third Years (0.27 and 0.13, respectively), while students in Fifth Year (-0.11) and First/Second Year (-0.21) have significantly lower levels of ESCS when compared to Third Year students.

The magnitude of the difference between the problem-solving mean score for Transition Year students and students in Third Year (32.5 points) is similar to the magnitude of the difference for digital reading (34.3 points) but is larger than for all other domains (which range from 21.1 to 27.9 points). Students in Transition Year perform significantly above their expected level in the computer-based assessment of problem solving (+ 5 points), given their performance in mathematics, reading and science (OECD, 2014, Table V.4.5).[18]

Table 3.3. Mean problem-solving mean scores by student grade (year) level, in Ireland

	%	Mean	SE	SD
First/Second Year	1.9	**443.2**	(10.30)	89.7
Third Year (Ref)	60.5	490.4	(3.34)	93.2
Transition Year	24.3	**522.9**	(4.97)	86.6
Fifth Year	13.3	497.8	(5.91)	95.0

Note. Significant differences are highlighted in bold.

[16] Of the 5,016 students that participated in PISA 2012 in Ireland, just three were from First Year. Therefore, for ease of analyses, students from First and Second Year are amalgamated.
[17] The ESCS scale is constructed to have an average of 0 across OECD countries and a standard deviation of 1. The mean ESCS score for students in Ireland in 2012 is 0.13.
[18] As expected performance on problem solving is based on previous performance in print mathematics, reading and science, socio-economic status is indirectly accounted for in this analysis.

3.4. Problem-solving Performance and Self-reported Dispositions Towards Problem Solving

As motivational and affective factors have been found to be associated with problem solving (Mayer and Wittrock, 2006), two indices to measure aspects of students' dispositions: perseverance; and openness to problem solving were included in PISA 2012. Perseverance was measured by asking students to indicate how well each of five statements related to them: 'I remain interested in the tasks that I start'; 'I continue working on tasks until everything is perfect'; 'when confronted with a problem I do more than is expected of me'; 'when confronted with a problem, I give up easily' and 'I put off difficult problems'. Openness to problem solving was assessed by asking students to indicate their levels of agreement with five statements: 'I can handle a lot of information'; 'I am quick to understand things'; 'I seek explanations for things', 'I can easily link facts together' and 'I like to solve complex problems'. Both of these indices were scaled to have an average of 0 and a standard deviation of 1 across all 34 OECD countries.[19]

Students in Ireland have significantly higher levels of reported perseverance (0.14) compared to the 28-country OECD average (0.00), but do not differ in terms of openness to problem solving (-0.02 and 0.00, respectively). Both openness to problem solving and perseverance are significantly and positively correlated with problem-solving performance (Table 3.4). The strength of the correlation between perseverance and problem-solving performance (r=.205) is about the same as for print mathematics (r=.257), while the correlation between openness to problem solving and performance on problem solving (r=.312) is somewhat weaker than for print mathematics (r=.404).

Table 3.4. Correlations between problem-solving performance and self-reported dispositions toward problem solving, in Ireland

	Problem solving		
	r	*t*	*p*
Openness to problem solving	.312	18.8	<.001
Perseverance	.250	11.7	<.001

The association between openness to problem solving and performance appears to be stronger in Ireland than on average across the 28 participating OECD countries. In Ireland, a one-point (i.e. one standard deviation) increase in openness to problem solving is associated with an increase of 22.6 points in problem-solving performance, compared to a 28-country OECD average of 14.8 points. Also, the relationship between openness to problem solving and performance is stronger among higher-achieving students than lower-achieving students: a one-point increase in openness to problem solving is associated with 26.9 point increase in performance among higher-achieving students (i.e. those performing at the 90th percentile) and a 20.6 point increase among lower-achieving students (i.e. those performing at the 10th percentile).

A similar pattern is evident for perseverance. A one-point increase in perseverance is associated with a 29.7-point increase in performance in Ireland and 24.6-point increase in performance across the 28-participating OECD countries. The relationship between perseverance and problem-solving performance is also stronger among higher-achieving students in Ireland: a one-point increase in perseverance is associated with a 38.5-point increase in performance among students at the 90th percentile compared to a 20.0-point increase at the 10th percentile.

[19] These indices formed part of the Student Questionnaire which was administered along with the paper-based assessment in all participating countries.

3.5. Problem-solving Performance and Use of ICTs

The assessment of problem solving was delivered on a computer-based platform; therefore, it is likely that familiarity with ICTs could have contributed to performance on the assessment. In Ireland, 97.0% of students report that they use a desktop, laptop or tablet computer at home while 63.5% indicate that they use a desktop, laptop or tablet computer at school (Table 3.5). Students who use a computer at home significantly outperform those who do not on the assessment of problem solving, by 30.6 points. However, when socio-economic status is accounted for, the difference shrinks to 11.2 points and is no longer significant. In Ireland, the difference in performance associated with use of computers at home, after adjusting for socio-economic status of students, is larger for problem solving (+11.2 points) than for any other domain (+4.8 points for print mathematics, +3.8 points for print reading, +2.8 points for science, +6.8 points for computer-based mathematics and +3.0 points for digital reading).

On the other hand, there is no significant difference between students who use a desktop, laptop or tablet at school and those who do not in terms of their problem-solving performance, even when socio-economic differences are accounted for.

Table 3.5. Mean problem-solving mean scores by whether a student uses a desktop, laptop or tablet at home and a school, in Ireland

	%	Mean	SE	SD
Uses desktop, laptop or tablet at home?				
Yes (ref)	97.0	500.5	(3.08)	91.9
No	3.0	**469.9**	(11.02)	101.0
Uses desktop, laptop or tablet at school?				
Yes (ref)	63.5	499.9	(3.49)	93.3
No	36.5	499.6	(3.92)	90.3

Note. Significant differences are highlighted in bold. Source: OECD (2014) tables V.4.25.

Interestingly, students in Transition Year are significantly more likely to report using ICT at school than students in other year levels but do not differ from students in other year levels (with the exception of students in Second Year) in terms of their use of ICT in mathematics lessons (Table 3.6).

Table 3.6. Mean use of ICT at school in general and in mathematics lessons by year level, in Ireland

		Use of ICT in school in general		Use of ICT in mathematics lessons	
	%	Mean	SE	Mean	SE
Second Year	1.9	**-.475**	(0.12)	**.114**	(0.12)
Third Year	60.5	**-.628**	(0.03)	-.147	(0.03)
Transition Year (ref)	24.3	.209	(0.03)	-.203	(0.03)
Fifth Year	13.3	**-.262**	(0.05)	-.090	(0.04)

Note. Significant differences are highlighted in bold.

4. Conclusions

This chapter presents some conclusions based on the initial outcomes of the computer-based assessment of problem solving in Ireland and should be read in conjunction with the Executive Summary presented at the beginning of this report. Four general themes are explored: problem solving and mathematics; equality of opportunity; computer-based assessments; and the performance of higher- and lower-achievers. Another report, *PISA and Project Maths*, which will explore the results of PISA 2012 in the 23 initial Project Maths schools and make comparisons with performance in non-initial schools, will include more in-depth analysis and recommendations relating to problem solving performance.

The present report is one of several in which, among other things, the competence of students in Ireland, and in one case adults, in a variety of domains (e.g. reading literacy) are compared with other countries (Perkins et al., 2013; Eivers & Clerkin, 2012; CSO, 2013). What is perhaps most striking about the findings reported here is how few statistically significant differences emerge between Ireland and the 28-country OECD average. This is in contrast to the results for mathematics, reading and science in PISA 2012 and in PIRLS and TIMMS in 2011; but not for literacy and numeracy in PIAAC 2011-12. However, given that the performance of students in Ireland on mathematics has been characterised as average in the earlier cycles of PISA and just slightly above average in 2012, perhaps it should come as no surprise that performance on the computer-based assessment of problem solving is not stronger in Ireland.

4.1. Problem Solving and Mathematics

Students in Ireland are performing at average levels on the computer-based assessments of problem solving and mathematics, while their performance is just slightly, but statistically significantly above average for print mathematics. The assessment of problem solving in PISA 2012 was designed so that domain specific knowledge would not be required; however, strong positive correlations were found between performance on problem solving and other domains (especially mathematics). In fact, about 64% of the problem-solving score reflects skills that are also measured in mathematics. Therefore, it seems unlikely that the performance of students in Ireland on PISA mathematics will improve substantially without a corresponding improvement in problem-solving performance and vice versa. This indicates a need to improve the general problem-solving skills of students in Ireland as well as their mathematics skills.

It is noteworthy that students in Ireland perform significantly below the OECD average on the print mathematics content area of Space & Shape. It is possible that there is some overlap in the skills required for both Space & Shape and problem solving. This could be investigated further, as Ireland’s lower performance on Space & Shape may be contributing to the lower than expected performance on the assessment of problem solving

With increased emphasis on problem solving in the new Project Maths curriculum, it is likely that the roll out of the new curriculum should in time affect performance in both mathematics and problem solving on assessments such as PISA. However, the effects of Project Maths on student learning need to be closely monitored, and adjustments made if goals are not being achieved. Evidence based on a small sample of students’ (from initial and non-initial schools) work suggests that students are being presented with tasks that do not require them to engage widely with the mathematical processes promoted through the revised syllabus and that students display less mastery in problem solving than they do in other mathematical processes such as mathematical procedures (Jeffes et al., 2013). It is likely that it will take time for the processes promoted through the new syllabus to become fully embedded. However, it is encouraging to note that approaches such as making links between different mathematics topics, applying what is learned in mathematics to real-life situations and working together in small groups are used more frequently in the initial 23 Project Maths schools compared to other schools, suggesting that these practices will become more widespread as Project Maths becomes more deeply embedded in classrooms.

Other policy initiatives, such as *The National Strategy to Improve Literacy and Numeracy among Children and Young People 2011-2020* (DES, 2011), which among other things aims to promote the development of problem-solving skills, and the revised curriculum for mathematics at primary level, which is currently under development, should also contribute to improved proficiency in problem solving among students in Ireland.

4.2. Equality of Opportunity

The school appears to be a relatively important influence on problem-solving performance in Ireland, with larger between-school differences noted for problem solving than for other domains. Given the large overlap between problem solving and other curricular areas, it seems likely that a greater emphasis on problem solving skills across all schools would not only improve proficiency on problem-solving assessments but also on assessments of other domains.

As with other domains, socio-economic status is positively associated with problem-solving achievement in Ireland. However, the amount of between-school variation in problem-solving performance that is explained by the socio-economic composition of schools in Ireland relates, almost entirely, to the component of problem-solving performance that is shared with mathematics performance. This indicates that students need a certain amount of academic proficiency to be able to develop effective problem-solving skills. Therefore, it is important that all students, including those from lower socio-economic backgrounds, are provided with opportunities to meet their academic potential in school so as not to hinder their development of problem-solving or other skills.

Furthermore, while it is encouraging that students with an immigrant background in Ireland have a significantly higher mean problem-solving score than the corresponding OECD average, these students are still performing significantly less well than native students in Ireland (487.9 and 501.2, respectively). Furthermore, when compared to students with similar mathematics, reading and science performance, immigrant students in Ireland perform less well in problem solving. Therefore, it seems important that efforts should be made to bring the performance of such students in line with the performance of native students in Ireland.

4.3. Computer-based Assessments

As the assessment of problem solving was delivered on a computer-based platform, it is possible that differences in students' level of familiarity with computers and with using computers as an assessment mode may have influenced their performance on problem-solving. While the vast majority of students in Ireland reported using a desktop computer, laptop or tablet at home (97%) or at school (64%), there are no significant differences between these students and those who do not use these ICTs at home or school in terms of problem-solving performance, when socio-economic status is accounted for. Students in Ireland may be familiar with using ICTs, but not necessarily for school-related tasks or in an assessment environment. Indeed, students in Ireland reported significantly lower levels of use of ICTs in school in general, in mathematics lessons and at home for school-related tasks when compared to the average across all 34 OECD countries.

In Ireland, student performance is over 18 points lower on the assessment of problem solving 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 just their performance on the computer-based assessment of mathematics and reading is accounted for. This indicates that the effect of computer delivery on performance is about nine points in Ireland. It seems that students in Ireland may have been disadvantaged on the computer-based assessments compared to students in other countries due to less familiarity with using computers (at home and at school) for school-related tasks. Given that in the next cycle of PISA only computer-based assessments (involving computer-based presentation of print-based items from previous PISA cycles as well as some new interactive science items) will be used in most countries, it is worth considering the potential impact of the change in mode of testing on performance. The field trial for the PISA 2015 cycle will include a mode effects study to determine the effect of different modes of delivery on student performance.

According to Jeffes et al. (2013), using computers to solve problems is one of the least frequent approaches used in mathematics lessons in Ireland. However, students in the initial 23 Project Maths reported significantly more frequent use of computers in mathematics lessons than students in other schools. Also, almost half of teachers in initial schools reported high usage of ICT during mathematics lessons (i.e. using ICT resources such as PC, data projector or mathematics software at least once a week), compared to about 30% in non-initial schools (Cosgrove, Perkins, Shiel, Fish & McGuinness, 2012). These findings indicate that computer use in mathematics lessons could become more widespread as Project Maths becomes more embedded. Furthermore, improvements in ICT infrastructure in post primary schools such as 100 Mbps broadband in all schools from September 2014 and the greater availability of devices should in turn contribute towards greater use of ICTs in schools.

It is also noteworthy that students in Transition Year perform significantly above their expected level (+ 5 points) for problem solving, given their performance in mathematics, reading and science.[20] One of the aims of Transition Year is to provide students with opportunities to participate in learning strategies that will help them develop a range of transferable critical thinking and creative problem-solving skills (Department of Education, 1993) through engagement in practical activities and student-directed learning. Thus, it may be that such strategies contributed to the better-than-

[20] Students participating in PISA in Ireland come from across a number of grade (year) levels: 61% of participating students are in Third Year, 24% are in Transition Year, 13% are in Fifth Year and the remaining 2% are in the First and Second Years. Across all domains, students in Transition Year obtain the highest mean score, possibly due to higher levels of socio-economic status and/or being in the education system longer. The higher-than-expected performance of Transition Year students in problem solving is in relation to their performance in mathematics, reading and science and therefore is unlikely to be related to socio-economic status.

expected performance among Transition Year students and it is likely that increased use of student-directed learning, a key feature of Project Maths, would improve problem-solving skills among all students. It is also likely that a greater level of familiarity with ICT in a school context contributed to the better than expected results for Transition Year students. While students in Transition Year did not report using ICT in mathematics classes more frequently than students in other years, use of ICT in school in general was significantly more frequent among Transition Year students than among students in other year levels. Smyth, Byrne and Hannan (2004) found that 86% of school surveyed offered IT studies (including European Computer Driver Licence (ECDL), computer programming and key board skills) as part of Transition Year and in 84% of schools these were offered as core subjects. The new framework for Junior Cycle (DES, 2012) is likely to promote many of the approaches and strategies used in Transition Year, and therefore should provide similar opportunities for the development of problem-solving skills and use of ICTs in lessons. Indeed, problem solving skills are inherent across the six key skills outlined in the new framework for Junior Cycle and ICT skills are explicitly outlined for each key skill.

4.4. The Performance of Higher- and Lower-achievers

In Ireland, lower-achieving students on the computer-based assessment of problem-solving are performing at about the same level as the corresponding OECD average. The performance of higher-achieving students in Ireland is somewhat lower than the corresponding OECD average, but not significantly so. Across all other domains, Ireland's performance is characterised by relatively good performance among lower-achieving students and a relative underperformance among higher-achieving students compared to other countries. It seems unlikely that Ireland's overall problem-solving performance will increase substantially without improvements at both the lower- and upper-end of the achievement distribution.

In Ireland, significant associations have been found between student dispositions towards problem solving (openness to problem solving and perseverance) and performance. Also, the relationship between openness to problem solving and performance, and between perseverance and performance, is stronger among higher-achieving students than lower-achieving students. Thus, encouraging more positive students' dispositions towards problem solving may be one approach to improving problem-solving performance, especially among higher-achieving students.

References

Cosgrove, J., Perkins, R., Shiel, G., Fish, R., & McGuinness, L. (2012). *Teaching and learning in Project Maths: Insights from teachers who participated in PISA 2012*. Dublin: Educational Research Centre.CSO

Department of Education (1993). *Transition Year Programme: Guidelines for schools*. Dublin: Author.

Department of Education and Skills. (2011). *Literacy and numeracy for learning and life: The national strategy to improve literacy and numeracy among children and young people, 2011-2020*. Dublin: Author.

Department of Education and Skills. (2012). *A framework for the Junior Cycle*. Dublin: Author.

Eivers, E., & Clerkin, A. (2012). *PIRLS & TIMSS 2011: Reading, mathematics and science outcomes for Ireland*. Dublin: Educational Research Centre.

Funke, J. (2010). Complex problem solving: A case for complex cognition? *Cognitive Processing*, Vol. 11, pp. 133-142.

Jeffes, J., Jones, E., Wilson, M., Lamount, E. Straw, S., Wheater, R. et al. (2013). *Research into the impact of Project Maths on student achievement, learning and motivation: Final report*. Slough: NFER.

Mayer, R. E., & Wittrock, R. C. (2006). Problem solving. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (2nd ed., pp. 287–304). Mahwah, NJ: Erlbaum.

OECD. (2004). *Problem solving for tomorrow's world: First measures of cross-curricular competencies from PISA 2003*. Paris: OECD publishing.

OECD. (2013a). *PISA 2012 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy*. Paris: OECD publishing.

OECD. (2013b). *What Students know and can do: Student performance in mathematics, reading and science (Volume I)*. Paris: OECD publishing.

OECD. (2013c). *Excellence through equity: Giving every student the chance to succeed (Volume II)*. Paris: OECD Publishing.

OECD. (2013d). *Ready to learn: Students' engagement, drive and self-beliefs (Volume III)*. Paris: OECD Publishing.

OECD. (2013e). *What makes a school successful: Resources, policies and practices (Volume IV).* Paris: OECD Publishing.

OECD. (2013f). *OECD skills outlook: First results from the survey of adult skills (PIAAC)*. Paris: OECD Publishing.

OECD. (2014). *Skills for Life: Student performance in problem solving (Volume V)*. Paris: OECD Publishing.

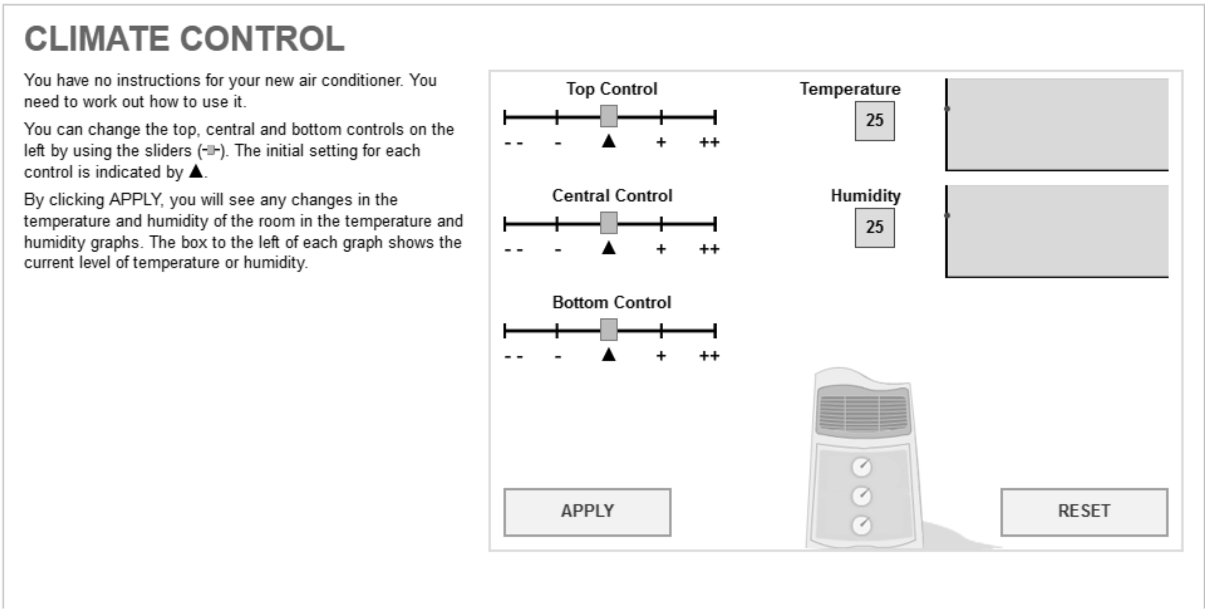
Perkins, R., Shiel, G., Merriman, B., Cosgrove, J. & Moran, G. (2013). *Learning for life: The achievements of 15-year-olds in Ireland on mathematics, reading literacy and science in PISA 2012*. Dublin: Educational Research Centre.

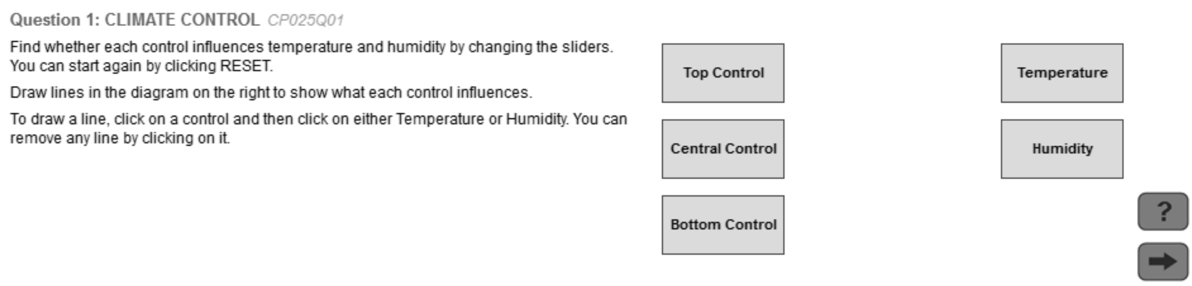
Smyth, E., Byrne, D. & Hannan, C. (2004). *The Transition Year Programme: An assessment*. Dublin: Liffey Press/ESRI.

Appendix A: Sample Passages and Questions from the Assessment of Problem Solving

This appendix contains a selection of items presented to students in the computer-based assessment of problem solving in PISA 2012. Released problem-solving items, as well as computer-based reading and mathematics items, can be viewed interactively at http://erasq.acer.edu.au.

Sample Unit 1: Climate Control





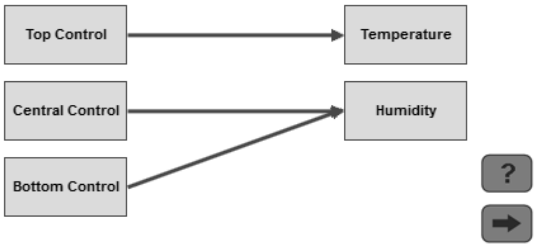
Response	Ireland	OECD
Full credit	48.4%	53.3%
Partial credit	16.9%	11.8%
Incorrect	32.8%	31.9%
Missing/Not reached	1.9%	3.0%

Context Technological/personal
Nature Interactive
Process Representing and formulating

Question 2: CLIMATE CONTROL *CP025Q02*

The correct relationship between the three controls, Temperature and Humidity is shown on the right.

Use the controls to set the temperature and humidity to the target levels. **Do this in a maximum of four steps.** The target levels are shown by the red bands across the Temperature and Humidity graphs. The range of values for each target level is 18-20 and is shown to the left of each red band. **You can only click APPLY four times and there is no RESET button.**



Response	Ireland	OECD
Full credit	12.8%	17.3%
Partial credit	19.3%	21.2%
Incorrect	56.7%	49.5%
Missing/Not reached	11.2%	12.0%

Context Technological/personal
Nature Interactive
Process Planning and executing

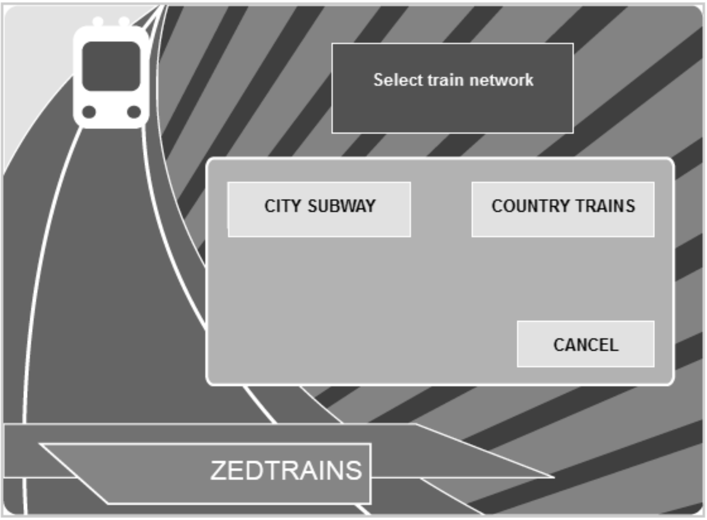
Sample Unit 2: Tickets

TICKETS

A train station has an automated ticketing machine. You use the touch screen on the right to buy a ticket. You must make three choices.

- Choose the train network you want (subway or country).
- Choose the type of fare (full or concession).
- Choose a daily ticket or a ticket for a specified number of trips. Daily tickets give you unlimited travel on the day of purchase. If you buy a ticket with a specified number of trips, you can use the trips on different days.

The BUY button appears when you have made these three choices. There is a CANCEL button that can be used at any time BEFORE you press the BUY button.



Question 1: TICKETS *CP038Q02*

Buy a full fare, country train ticket with two individual trips.

Once you have pressed BUY, you cannot return to the question.

Response	Ireland	OECD
Correct	66.3%	58.0%
Incorrect	32.9%	40.3%
Missing/Not reached	0.8%	1.7%

Context Technological/social
Nature Interactive
Process Planning and executing

Question 2: TICKETS *CP038Q01*

You plan to take four trips around the city on the subway today. You are a student, so you can use concession fares.

Use the ticketing machine to find the cheapest ticket and press BUY.

Once you have pressed BUY, you cannot return to the question.

Response	Ireland	OECD
Full credit (student must compare the daily subway tickets with concession fares and the individual concession fare ticket with four trip screen before buying ticket)	28.7%	27.0%
Partial credit (students who buy one of the two tickets without comparing the prices for the two only)	46.1%	46.3%
Incorrect	24.2%	24.1%
Missing/Not reached	1.0%	2.6%

Context Technological/social
Nature Interactive
Process Exploring and understanding

Question 3: TICKETS *CP038Q03*

You want to buy a ticket with two individual trips for the city subway. You are a student, so you can use concession fares.

Use the ticketing machine to purchase the best ticket available.

Response	Ireland	OECD
Correct	52.7%	42.9%
Incorrect	45.9%	55.3%
Missing/Not reached	1.4%	1.8%

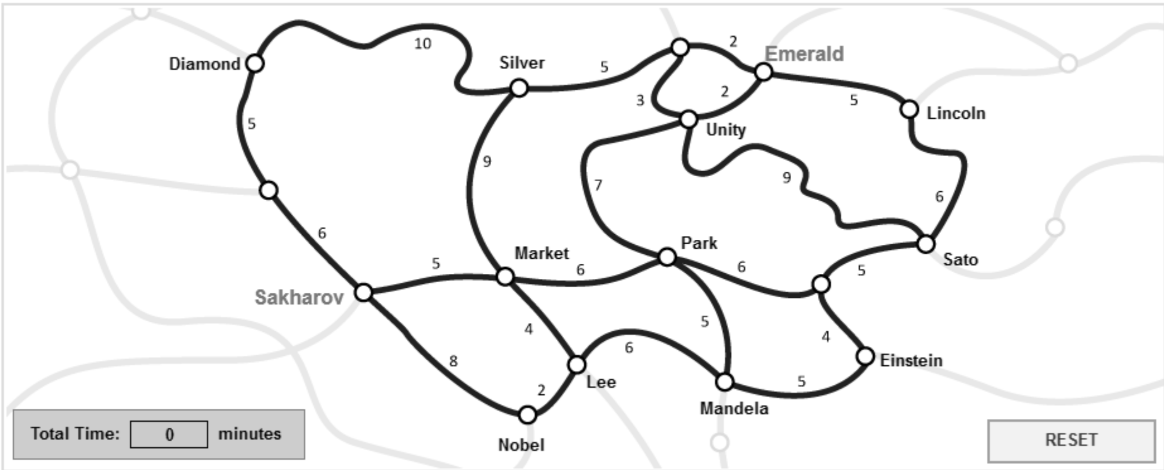
Context Technological/social
Nature Interactive
Process Monitoring and reflecting

Sample Unit 3: Traffic

TRAFFIC

Here is a map of a system of roads that links the suburbs within a city. The map shows the travel time in minutes at 7:00 am on each section of road. You can add a road to your route by clicking on it. Clicking on a road highlights the road and adds the time to the **Total Time** box.

You can remove a road from your route by clicking on it again. You can use the RESET button to remove all roads from your route.



Question 1: TRAFFIC *CP007Q01*

Pepe is at Sakharov and wants to travel to Emerald. He wants to complete his trip as quickly as possible. What is the shortest time for his trip?

- 20 minutes
- 21 minutes
- 24 minutes
- 28 minutes

Response	Ireland	OECD
Correct (option A)	87.7%	86.4%
Incorrect	12.3%	12.6%
Missing/Not reached	0.0%	1.0%

Context Non-technological/social
Nature Static
Process Planning and executing

Question 2: TRAFFIC *CP007Q02*

Maria wants to travel from Diamond to Einstein. The quickest route takes 31 minutes.

Highlight this route.

Response	Ireland	OECD
Correct	67.0%	70.4%
Incorrect	24.4%	23.6%
Missing/Not reached	8.6%	6.0%

Context	Non-technological/social
Nature	Static
Process	Planning and executing

Question 3: TRAFFIC *CP007Q03*

Julio lives in Silver, Maria lives in Lincoln and Don lives in Nobel. They want to meet in a suburb on the map. No-one wants to travel for more than 15 minutes.

Where could they meet?

Response	Ireland	OECD
Correct	73.7%	78.2%
Incorrect	22.4%	16.6%
Missing/Not reached	3.9%	5.2%

Context	Non-technological/social
Nature	Static
Process	Monitoring and reflecting

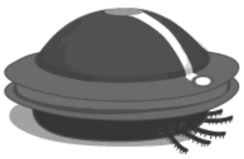
Sample Unit 4: Robot Cleaner

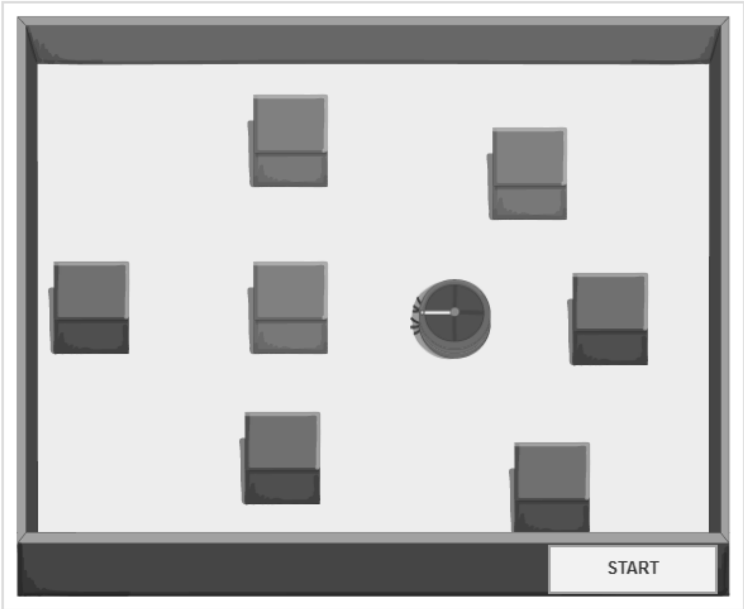
ROBOT CLEANER

The animation shows the movement of a new robotic vacuum cleaner. It is being tested.

Click the START button to see what the vacuum cleaner does when it meets different types of objects.

You can use the RESET button to place the vacuum cleaner back in its starting position at any time.





Question 1: ROBOT CLEANER *CP002Q08*

What does the vacuum cleaner do when it meets a red block?

- It immediately moves to another red block.
- It turns and moves to the nearest yellow block.
- It turns a quarter circle (90 degrees) and moves forward until it meets something else.
- It turns a half circle (180 degrees) and moves forward until it meets something else.

Response	Ireland	OECD
Correct (option C)	58.4%	63.1%
Incorrect	41.3%	36.1%
Missing/Not reached	0.3%	0.8%

Context Non-technological/social
Nature Static
Process Exploring and understanding

Question 2: ROBOT CLEANER *CP002Q07*

At the beginning of the animation, the vacuum cleaner is facing the left wall. By the end of the animation it has pushed two yellow blocks.

If, instead of facing the left wall at the beginning of the animation, the vacuum cleaner was facing the right wall, how many yellow blocks would it have pushed by the end of the animation?

- 0
- 1
- 2
- 3

Response	Ireland	OECD
Correct (option B)	40.8%	46.8%
Incorrect	58.6%	52.1%
Missing/Not reached	0.6%	1.1%

Context Non-technological/social
Nature Static
Process Exploring and understanding

Question 3: ROBOT CLEANER *CP002Q06*

The vacuum cleaner's behaviour follows a set of rules. Based on the animation, write a rule that describes what the vacuum cleaner does when it meets a yellow block.

Response	Ireland	OECD
Full credit	13.1%	14.9%
Partial credit	56.1%	64.6%
Incorrect	28.3%	16.3%
Missing/Not reached	2.5%	4.2%

Context Non-technological/social
Nature Static
Process Representing and formulating

Educational Research Centre, St Patrick's College, Dublin 9
http://www.erc.ie

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