Problem Solving
for Tomorrow’s World

RESULTS OF NEW ZEALAND
15-YEAR-OLDS IN THE 2003 PISA SURVEY
Acknowledgements

We are indebted to the many students, teachers and principals who participated in this study. Their efforts and assistance have provided our country with a valuable resource.

We also wish to acknowledge the assistance from our international colleagues from the Australian Council for Educational Research (ACER) and the Statistics and Indicators Division of the Organisation for Economic Co-operation and Development (OECD) for the work done in preparing the international report on which this summary report is based.
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Overview

What is PISA?
The Programme for International Student Assessment (PISA) is a three-yearly international survey of 15-year-olds that assesses their knowledge and skills for modern life. In 2003, the survey was carried out in the 30 Organisation for Economic Co-operation and Development (OECD) member countries, plus 11 other countries, and it tested over a quarter of a million students, including 4500 from New Zealand. The 2003 cycle also included a one-off survey of problem-solving.

What does PISA tell us about problem-solving?
PISA tells us how well students can use problem-solving skills in real-life situations. Specifically, it shows how well they can solve problems that require decision making, systems analysis and design, and trouble shooting.

How good are New Zealand students at problem-solving?
On average, New Zealand students do significantly better at problem-solving than other students across the OECD countries.

More precisely, New Zealand has more 15-year-old students with high proficiency and fewer students with low proficiency than most countries. On average, approximately two-thirds of New Zealand students, compared with about half of all students across the OECD countries, can solve problems that require more than a basic level of proficiency. Over a quarter of New Zealand students are at the highest level of proficiency, are capable of solving advanced problems, and are described as ‘reflective, communicative’ problem-solvers.

Only two OECD countries, Korea and Finland, scored higher than New Zealand students in problem-solving, on average. Five other OECD countries had average scores not significantly different from New Zealand. New Zealand has a relatively wide distribution of achievement scores in problem-solving, as do most other OECD countries. However, the distribution of scores for the two top performing countries, Finland and Korea, are narrow by comparison.

How does the problem-solving performance in New Zealand compare with the results in the reading, mathematics, and science assessments in PISA 2003?
Overall, New Zealand students typically did better in problem-solving than in mathematics, science or reading. This suggests that students have the potential to achieve better results in these three curriculum subjects, given that their generic problem-solving skills are relatively higher.

What are the differences in problem-solving between different groups in New Zealand?

- There is no significant difference between the performance of boys and girls.
- Achievement in problem-solving across the four main ethnic groups varies considerably, with European/Pākehā and Asian students performing significantly better on average than Māori and Pasifika students. Pasifika students’ average scores are significantly below the scores of the other three ethnic groups.
- Other student characteristics that are strongly linked to higher average scores in problem-solving include higher parental occupational status and attending higher decile schools.

1 Throughout this report, the term significantly refers to statistical significance at the 0.05 level.
• The average performance of Maori students in problem-solving is closer to the OECD average in comparison to their performance in the other PISA domains of reading, mathematics and science.
**Background: the PISA survey**

PISA surveys the knowledge and skills of 15-year-olds in the principal industrialised countries. The product of collaboration between participating governments through the OECD, it draws on leading international expertise to develop valid comparisons across countries and cultures.

PISA 2003 is the second assessment in the series. In this survey:

- Well over a quarter of a million students in 41 countries took part. All 30 OECD member countries participated, as well as ‘partner countries’ in Asia, Africa, Eastern Europe, and Latin America.
- Each student took a two-hour written test in their school.
- Students were assessed in mathematics, reading, science, and problem-solving. Mathematics was the main focus in 2003, while reading was the main focus in the first survey in 2000. The next PISA assessment in 2006 will focus on student performance in science.

The key features of the PISA approach are:

- Its policy orientation, with design and reporting methods determined by the need of governments to draw policy lessons.
- The innovative ‘literacy’ concept, which is concerned with the capacity of students to apply knowledge and skills in key subject areas and to analyse, reason, and communicate effectively as they pose, solve, and interpret problems in a variety of situations.
- Its inclusion of assessment that is not restricted to particular areas of the school curriculum. The assessment of ‘problem-solving’ in 2003, the subject of this report, was the first such ‘cross-curricular’ assessment.
- Its regularity, which will enable countries to monitor their progress in meeting the key learning objectives over time.
- Its consideration of student performance alongside the background characteristics of students at home and school in order to explore some of the main features associated with educational success. Each participating student and school completed a questionnaire that allowed a wide range of background information to be considered alongside student performance.
- Its breadth of geographical coverage, as the countries that have participated so far represent one-third of the world’s population and almost nine-tenths of the world’s gross domestic product (GDP).

The comparisons made below set New Zealand students’ performance alongside that of students in the participating OECD countries, which are the countries in the survey most comparable to New Zealand: it excludes countries such as Tunisia, Peru and Russia from the analysis. A total of 29 OECD countries reported results in 2003. (The United Kingdom participated but did not meet the sampling requirements.)

**Assessing problem-solving in PISA 2003**

The collection of information about problem-solving skills in PISA 2003 was carried out to address concerns from the OECD countries that students' capabilities in reading, mathematics, and science do not tell us enough about their overall capacity to solve problems in real-life situations beyond the context of the school curriculum.
According to the agreed PISA definition, problem-solving is:

... an individual’s capacity to use cognitive processes to confront and resolve real, cross-disciplinary situations where the solution path is not immediately obvious and where the literacy domains or curricular areas that might be applicable are not within a single domain of mathematics, science or reading.

PISA 2003 Learning for Tomorrow’s World, OECD: p. 26

The problem-solving component within PISA 2003 examines how well young adults are prepared to meet the challenges of today’s knowledge societies, focusing on young people’s ability to use their knowledge and skills to meet real-life challenges beyond the classroom.

The concept of problem-solving in PISA is defined by five dimensions:

- **Problem types:** PISA 2003 assesses three types of problems: decision-making, system analysis and design, and trouble-shooting. For a description of what these three types of problems involve, see Appendix B. Examples of the three different types of problems are given in Boxes A to C of this report:
  - A decision-making problem requiring students to find a suitable time and date to go to the cinema, when shown a timetable and a set of constraints (Box A, pages 9-11).
  - A systems analysis and design problem requiring students to organise dormitory allocations in a children’s camp, given a set of rules and other information (Box B, pages 13-15).
  - A trouble-shooting problem requiring students to diagnose a problem with the flow of water through an irrigation network (Box C, pages 19-21).

- **Problem context:** problems are set in contexts outside the classroom and school curriculum, such as personal life, work and leisure, and community and society.

- **Disciplines:** the domain covers a wide range of disciplines and thus complements the main PISA domains of mathematical, scientific, and reading literacy.

- **Problem-solving processes:** the assessment is designed to find out the extent to which students are able to understand, characterise, represent and solve problems effectively. Students should also be able to reflect on the solution and to communicate it to others.

- **Reasoning skills:** beyond drawing on students’ knowledge, good problems also draw on their reasoning skills.

**Problem-solving scores and problem-solving proficiency in PISA 2003**

As in other PISA domains, problem-solving in PISA is scored on a scale assigning a point score to each student. Each task is given a score according to its difficulty, and the students are assigned individual scores according to the highest difficulty of task that they are likely to be able to perform.

The scale is devised with an average score for all the OECD countries of 500 and a standard deviation of 100, meaning that about two-thirds of students score between 400 and 600 points.

To aid interpretation, tasks are ranked at three ‘proficiency levels’ with each student assigned to the highest level at which they could perform the required tasks. Specifically, a student must be capable of getting a majority of tasks at a given proficiency level correct in order to be ranked at that level. Some students do not reach even the lowest level, Level 1. This does not mean that they are unable to perform any PISA problem-solving tasks but
it does mean they would get the majority of simple tasks wrong. Table 1 provides detailed information on the three proficiency levels.

Table 1: PISA problem-solving proficiency at different levels

<table>
<thead>
<tr>
<th>Level and corresponding range of point scores</th>
<th>Basic problem-solvers</th>
<th>Reasoning, decision-making problem-solvers</th>
<th>Reflective, communicative problem-solvers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>405-499</td>
<td>Students proficient at Level 1 solve problems where they have to deal with only a single data source containing discrete, well-defined information. Students at this level are generally not able to solve multifaceted problems that involve more than one data source or those that require reasoning. Students below Level 1 (less than 405 score points) are able to deal only with straightforward problems and structured tasks that require students to give responses based on facts or to make observations with few or no inferences. They are characterised as weak or emergent problem-solvers.</td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td>499-592</td>
<td>Students proficient at Level 2 use reasoning and analytic processes and can solve problems requiring decision-making skills. Students apply various types of reasoning to analyse situations and solve problems that require them to make a decision from well-defined alternatives.</td>
<td></td>
</tr>
<tr>
<td>Level 3</td>
<td>592 or above</td>
<td>Students proficient at Level 3 typically think about underlying relationships in problems and relate these to solutions as well as analysing situations and making decisions and communicating solutions clearly to others.</td>
<td></td>
</tr>
</tbody>
</table>

*The points assigned to each task according to its difficulty follow a scale that has been calibrated so that the OECD average point score is 500 and the standard deviation for students in the OECD countries is 100.

Students below Level 1 (less than 405 score points) are able to deal only with straightforward problems and structured tasks that require students to give responses based on facts or to make observations with few or no inferences. They are characterised as weak or emergent problem-solvers.

Appendix A gives more detail about the characteristics of problem-solvers at these levels. The boxes in this report give examples of problem-solving tasks at varying levels of difficulty.
A profile of student problem-solving performance in New Zealand

The PISA survey gives a profile of the 15-year-old student population in terms of what are the most difficult problem-solving tasks each student is able to perform. This information can be presented in terms of how many students are proficient at various levels of problem-solving as well as in terms of how well New Zealand measures up to the international benchmarks.

Distribution of problem-solving proficiency

Nine out of ten students in New Zealand are able to solve at least basic problems, at Level 1, most of the time. Figure 1 gives a profile of student problem-solving proficiency, comparing New Zealand students with the average for the OECD countries. In common with other diagrams in this report that provide information on sub-groups of New Zealand students, it presents the information in two ways. The top diagram shows the proportion of students at each proficiency level. The graph below shows how many students can perform at least at each level. For example, while 25% of New Zealand students are classified at Level 1 in problem-solving, 90% of all students are capable of solving Level 1 problems as this group also includes students classified at Levels 2 and 3.

The results in Figure 1 show that the percentage of weak problem-solvers is lower in New Zealand than for the OECD countries on average (10% rather than 17% below Level 1), and the percentage of students able to tackle complex problems at Level 3 is considerably higher than on average (28% rather than 18%). Two-thirds of New Zealand’s 15-year-olds can use reasoning and decision-making skills to solve problems that require more than basic Level 1 skills compared with around half of students internationally.

Overall, problem-solving is a strong area of performance for New Zealand students. These results show their substantial advantage over students in many other OECD countries. New Zealand is one of a group of seven OECD countries with over a quarter of students at Level 3 in problem-solving proficiency. Within this group, Australia and Canada have similar proportions of students at each proficiency level to New Zealand, but Japan and Korea have around one-third of students proficient at Level 3. In terms of low proficiency, the top performing OECD countries, Korea and Finland, have only 5% of students at below Level 1 in problem-solving proficiency compared with 10% of New Zealand students.

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1 A student is said to be at Level 1 if they get more than 50% of tasks correct in a test of random Level 1 tasks but less than 50% in a test of Level 2 tasks.
Figure 1: Problem-solving proficiency profile - New Zealand compared with the OECD average

A) Profile of students by their highest level of problem-solving proficiency

<table>
<thead>
<tr>
<th></th>
<th>New Zealand</th>
<th>OECD Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Weak” problem solvers</td>
<td>16%</td>
<td>17%</td>
</tr>
<tr>
<td>(below Level 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Basic” problem solvers</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>(Level 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Reasoning” problem solvers</td>
<td>36%</td>
<td>34%</td>
</tr>
<tr>
<td>(Level 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Reflective” problem solvers</td>
<td>28%</td>
<td>18%</td>
</tr>
<tr>
<td>(Level 3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B) Percentage of students capable of solving problems at each successive level

1. Diagram A represents the PISA proficiency levels of a typical group of 25 students (figures may not total to 25 due to rounding). For a description of Proficiency Levels, see Table 1 and Appendix A of this report.
Box A: Illustration of basic problem-solving proficiency in PISA

The following examples of two ‘decision-making’ problems in PISA 2003 help to illustrate the distinction between Level 1 and Level 2 tasks. Students are presented with a significant amount of information and constraints that determine which film they are able to go to see. Those with a basic level of decision-making proficiency will normally succeed at the second question, requiring just temporal constraints to be taken into account. A higher level of proficiency (Level 2) is required to fully answer the first question, in which time considerations must be merged with other constraints. However, students who give a partially correct answer to the first question also get credit at Level 1.
Box A continued ...

**CINEMA OUTING**

This problem is about finding a suitable time and date to go to the cinema.

Isaac, a 15-year-old, wants to organise a cinema outing with two of his friends, who are of the same age, during the one-week school holiday. The holiday begins on Saturday, 24th March and ends on Sunday, 1st April.

Isaac asks his friends for suitable dates and times for the outing. The following information is what he received.

*Tana:* "I have to stay home on Monday and Wednesday afternoons for music practice between 2:30 and 3:30"

*James:* "I have to visit grandmother on Sundays, so it can't be Sundays. I have seen *Pokamin* and don't want to see it again."

Isaac’s parents insist that he only goes to movies suitable for his age and does not walk home. They will fetch the boys home at any time up to 10 pm.

Isaac checks the movie times for the holiday week. This is the information that he finds.

---

**TIVOLI CINEMA**

Advance Booking Number: 019 244 2300  
24 hour phone number: 019 244 2007  
Bargain Day Tuesdays: All films $3

**Films showing from Fri 23rd March for two weeks:**

<table>
<thead>
<tr>
<th>Children in the Net</th>
<th>Pokamin</th>
</tr>
</thead>
<tbody>
<tr>
<td>113 mins 2:00 pm (Mon-Fri only) 9:35 pm (Sat/Sun only)</td>
<td>Suitable only for persons of 12 years and over</td>
</tr>
<tr>
<td>105 mins 1:40 pm (Daily) 4:35 pm (Daily)</td>
<td>Parental Guidance. General viewing, but some scenes may be unsuitable for young children</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monsters from the Deep</th>
<th>Enigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>164 mins 7:35 pm (Fri/Sat only)</td>
<td>Suitable only for persons of 18 years and over</td>
</tr>
<tr>
<td>144 mins 3:00 pm (Mon-Fri only) 6:00 pm (Sat/Sun only)</td>
<td>Suitable only for persons of 12 years and over</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carnivore</th>
<th>King of the Wild</th>
</tr>
</thead>
<tbody>
<tr>
<td>148 mins 6:30 pm (Daily)</td>
<td>Suitable for persons of all ages</td>
</tr>
<tr>
<td>117 mins 2:35 pm (Mon-Fri only) 6:50 pm (Sat/Sun only)</td>
<td></td>
</tr>
</tbody>
</table>

---
Box A continued ...

**Question 1: CINEMA OUTING**
(This is a Level 2 question if answered completely correctly, but partially correct answers are associated with Level 1 - see below)

Taking into account the information Isaac found on the movies, and the information he got from his friends, which of the six movies should Isaac and the boys consider watching?

Circle "Yes" or "No" for each movie.

This problem is about finding a suitable time and date to go to the cinema.

<table>
<thead>
<tr>
<th>Movie</th>
<th>Should the three boys consider watching the movie?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children in the Net</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Monsters from the Deep</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Carnivore</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Pokamin</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Enigma</td>
<td>Yes / No</td>
</tr>
<tr>
<td>King of the Wild</td>
<td>Yes / No</td>
</tr>
</tbody>
</table>

A fully correct answer – Yes, No, No, No, Yes, Yes, is associated with a score of 522 (Level 2).
A partially correct response – where one of these answers is wrong – is associated with a score of 442 (Level 1).

**Question 2: CINEMA OUTING**
(This is a Level 1 question)

Taking into account the information Isaac found on the movies, and the information he got from his friends, which of the six movies should Isaac and the boys consider watching?

If the three boys decided on going to “Children in the Net”, which of the following dates is suitable for them?

A  Monday, 26th March  
B  Wednesday, 28th March  
C  Friday, 30th March  
D  Saturday, 31st March  
E  Sunday, 1st April

A correct answer (C) is associated with a score of 468 points (Level 1).
New Zealand students' performance against the international benchmarks

It is clear from these results by proficiency level that New Zealand students perform relatively well in problem-solving, by international standards. This can be shown further by comparing the distribution of scores on the PISA scale to some international benchmarks.

Mean problem-solving literacy

One commonly used benchmark that sums up the performance of all students is their mean (average) score. The overall average for the OECD countries is set at 500 points with a standard deviation of 100, indicating that about two-thirds of students internationally score between 400 and 600. New Zealand students estimated average score in problem-solving is 533. This is a strong performance by international standards, significantly above the OECD average. Due to the fact that the averages of different countries are close and that testing a sample of students can provide only an estimate of the performance of the whole student population, it is not possible to give a precise rank order for New Zealand students’ average among the 29 OECD countries with valid results. However, we can say with confidence that New Zealand students’ average score in problem-solving is significantly higher than students in 21 other OECD countries, lower than students in two countries, and similar to students in five other countries, as shown in Table 2.

Table 2: Average problem-solving scores, OECD countries, PISA 2003

<table>
<thead>
<tr>
<th>Significantly higher than New Zealand</th>
<th>No significant difference from New Zealand</th>
<th>Significantly lower than New Zealand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea 550</td>
<td>Japan 547</td>
<td>Netherlands 520</td>
</tr>
<tr>
<td>Finland 548</td>
<td>New Zealand 533</td>
<td>Iceland 505</td>
</tr>
<tr>
<td>Australia 530</td>
<td>France 519</td>
<td>Spain 482</td>
</tr>
<tr>
<td>Canada 529</td>
<td>Denmark 51</td>
<td>USA 477</td>
</tr>
<tr>
<td>Belgium 525</td>
<td>Czech Republic 516</td>
<td>Portugal 470</td>
</tr>
<tr>
<td>Switzerland 521</td>
<td>Germany 513</td>
<td>Italy 470</td>
</tr>
<tr>
<td></td>
<td>Sweden 509</td>
<td>Greece 449</td>
</tr>
<tr>
<td></td>
<td>Austria 506</td>
<td>Turkey 408</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mexico 384</td>
</tr>
</tbody>
</table>

Note: The United Kingdom took part in the survey but did not meet the sampling requirements. Eleven non-OECD countries/territories also took part. Of these, only Hong Kong performed better than New Zealand with an average score of 548, and Liechtenstein and Macao-China had scores similar to New Zealand. The other non-OECD countries scored significantly below New Zealand.

Distribution of problem-solving literacy

Figure 2 shows a wider set of benchmarks. This figure compares the distribution of New Zealand problem-solving scores with the OECD average and also with two high-performing countries, Finland and Japan.

Figure 2 shows that, at each point in the distribution between the 5th and 95th percentile, New Zealand students have higher problem-solving scores than the OECD average. For example, New Zealand students score an average of 42 points above other students in the OECD countries at the 5th percentile. This gap is smaller at the 95th percentile (26 points).

The top 25% of New Zealand students score above 600 points on average, almost the same as Finnish students. The overall distribution of scores for Finland is relatively narrow compared to New Zealand and the main point of difference in achievement is at the lower end of the scale. For example, the bottom 5% of scores for New Zealand fell below 370 points; the equivalent score for Finnish students is 409 points. Overall, less than 5% of Finnish students scored below 400 points.
On the other hand, Japan has a wider distribution of problem-solving performance than New Zealand, as shown in Figure 2. The main difference between the two countries is that although their average scores are not significantly different, the high-performing Japanese students do better than their New Zealand counterparts. This is particularly noticeable at the 95th percentile, which is 23 points higher than the 95th percentile in New Zealand. However, there is no other OECD country whose students score significantly higher than New Zealand students at the upper quartile or at the 95th percentile. Box B below illustrates a Level 3 problem-solving task, a level at which 28% of New Zealand students are proficient.

**Figure 2: Distribution of New Zealand problem-solving scores against international benchmarks**

![Diagram showing distribution of scores](image)

It is interesting to compare Canada and New Zealand because they have similar average scores in problem-solving and the populations of both countries have fairly diverse ethnic and social characteristics, compared with Finland or Japan. However, although Canadian students have a much stronger mathematics performance on average than New Zealand students at the 5th percentile, it is not the case in problem-solving, where our weakest problem-solvers achieve similar scores to the Canadians.

**Box B: Illustration of higher level problem-solving proficiency in PISA**

The following example of a ‘systems analysis and design’ question shows the kind of task that a ‘reflective, communicative’ problem-solver (at proficiency Level 3) should be able to complete. Students just meeting Level 3, with a score of about 600, have about a 50% chance of doing this kind of problem, whereas students with a rating of 650, the difficulty level assigned to the question, have a higher chance (62%) of completing it. A quarter of New Zealand students have a score of at least 600, and one in ten has a score of at least 650.

In this exercise, the students must assign adults and children to dormitories at a camp, taking into account a series of constraints. A correct solution requires them to combine different pieces of information about both the
age and gender of the individuals involved and to take into account the capacities of different dormitories. While a certain amount of trial and error can be used in working through the first phases to understand the problem, the successful solution requires the students to monitor and adjust partial solutions relative to a number of interrelated conditions and to communicate the solution clearly as well. The requirement to manage interactions simultaneously with the development of a unique solution is what makes the problem a Level 3 task.

**CHILDREN’S CAMP**

The Zedish Community Service is organising a five-day Children’s Camp. 46 children (26 girls and 20 boys) have signed up for the camp, and 8 adults (4 men and 4 women) have volunteered to attend and organise the camp.

<table>
<thead>
<tr>
<th>Table 1: Adults</th>
<th>Table 2: Dormitories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mrs Madison</td>
<td>Name</td>
</tr>
<tr>
<td>Mrs Carroll</td>
<td>Red</td>
</tr>
<tr>
<td>Ms Grace</td>
<td>Blue</td>
</tr>
<tr>
<td>Ms Kelly</td>
<td>Green</td>
</tr>
<tr>
<td>Mr Stevens</td>
<td>Purple</td>
</tr>
<tr>
<td>Mr Neill</td>
<td>Orange</td>
</tr>
<tr>
<td>Mr Williams</td>
<td>Yellow</td>
</tr>
<tr>
<td>Mr Peters</td>
<td>White</td>
</tr>
</tbody>
</table>

**Dormitory rules:**

1. Boys and girls must sleep in separate dormitories.

2. At least one adult must sleep in each dormitory.

3. The adult(s) in a dormitory must be of the same gender as the children.

**Question 1: CHILDREN’S CAMP**

Dormitory Allocation.
Fill the table to allocate the 46 children and 8 adults to dormitories, keeping to all the rules.

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of boys</th>
<th>Number of girls</th>
<th>Name(s) of adult(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A correct answer, associated with a score of 650, requires students to give answers that meet six conditions:

- Total girls = 26
- Total boys = 20
- Total adults = four female and four male
- Total (children and adults) per dormitory is within the limit for each dormitory
- People in each dormitory are of the same gender
- At least one adult must sleep in each dormitory to which children have been allocated

**Overall variation within New Zealand**

Student performance in problem-solving varies greatly within New Zealand, but to a lesser extent than on average across OECD countries. As already stated, the gap between the top and bottom 5% of New Zealand students is 312 points in problem-solving compared with 328 in the OECD countries. The equivalent figures for the gap between the top and bottom quartiles are 133 points and 137 points respectively (see Figure 2 above), a much smaller gap and one that is not statistically significant.

A summary measure of variation across the whole distribution is the standard deviation. This is 100, on average, for the OECD countries and is significantly lower, 96, for New Zealand. It therefore appears that New Zealand students have less variation in problem-solving performance than students do, on average, for the OECD countries, and this is accounted for, in particular, by smaller variations at the extremes of the distribution. This is in contrast to other areas of PISA: in reading, the standard deviation for New Zealand is above the OECD average; in mathematics and science, it is around the average.

**Problem-solving performance relative to mathematics**

In PISA 2003 there is a high correlation between student performances in the four domains of mathematics, science, reading and problem-solving. In particular, the students who did well in mathematics also tended to do well in problem-solving. Analysis by the OECD shows that there is a considerable overlap in the requirements of these two domains, but they also note some differences. Students are least likely to score the same in mathematics as in problem-solving when tackling mathematical questions that require more knowledge of processes and mathematical rules, as opposed to tasks concentrating more on pure analytical reasoning.

As Figure 3 shows, New Zealand was one of twelve countries where the average score in problem-solving was significantly higher than the average score in mathematics. The relative standing of a country’s performance in mathematics and in problem-solving can be compared because the scores are both scaled with a mean of 500 and a standard deviation of 100 among OECD countries. Differences in a country’s average score for both mathematics and problem-solving show the difference in performance relative to the OECD average.
According to the OECD's international report:

Stronger problem-solving competencies and weaker mathematics performance may indicate that the mathematics instruction provided does not fully exploit the potential of students.

Problem-Solving for Tomorrow's World, OECD 2004, p. 57

From a positive perspective, these results suggest that some students are equipped with reasoning skills that could allow them to raise their performance in mathematics with the right kind of instruction.
Who are the stronger and weaker students in problem-solving in New Zealand?

This section looks further at the distribution of problem-solving performance within New Zealand by considering the proficiency profile of various groups of students. It compares boys with girls, members of different ethnic groups, members of different socio-economic groups, and students in different schools.

These breakdowns indicate the extent to which particular groups of students may have a lower level of proficiency in problem-solving, even though there may also be a number of students within these groups who do very well. Overall, one-third of New Zealand students (35%) have only basic problem-solving proficiency (Level 1). To what extent should efforts to help students improve their problem-solving capacity focus on certain groups more than others?

Gender differences in problem-solving performance

Boys and girls in New Zealand have an almost identical proficiency profile as problem-solvers, and this is also true among boys and girls within each ethnic group. This is in contrast to the other three domains examined in PISA; in reading, girls have a significantly stronger performance, whereas in science and mathematics, boys have a small but significant advantage. The fact that this gender difference is not repeated in problem-solving is interesting. In all but three OECD countries there is no significant gender difference, which suggests that female and male students may utilise their own gender-specific strengths in cross-disciplinary tasks, leading to relatively equal outcomes in problem-solving performance.

Differences in problem-solving by ethnic group

Within each main ethnic group in New Zealand, there are some students who are highly proficient in problem-solving and others who perform poorly. On the other hand, the proficiency profile of the four groups (Pākehā/European, Asian, Māori, and Pasifika) varies considerably. As Figure 4 shows, Pākehā/European and Asian students have relatively large numbers of students with high proficiency in problem-solving, whereas Māori and Pasifika students have more students at the lower end of the proficiency scale.

Almost three-quarters of Pākehā/European and Asian students are capable of solving problems more difficult than the basic Level 1 tasks and one-third of students in these two ethnic groups can solve advanced problems at Level 3. However, Asian students are more likely than Pākehā/European students to be weak problem-solvers below Level 1, which is reflected in the wider spread of scores for Asian students in problem-solving, as it is in the other PISA domains.
Figure 4: Problem-solving proficiency profile by ethnic group

A) Profile of students by their highest level of problem-solving proficiency

<table>
<thead>
<tr>
<th></th>
<th>&quot;Weak&quot; problem solvers (Below level 1)</th>
<th>&quot;Basic&quot; problem solvers (Level 1)</th>
<th>&quot;Reasoning&quot; problem solvers (Level 2)</th>
<th>&quot;Reflective&quot; problem solvers (Level 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pākehā</td>
<td>5%</td>
<td>21%</td>
<td>39%</td>
<td>25%</td>
</tr>
<tr>
<td>Asian</td>
<td>0%</td>
<td>21%</td>
<td>39%</td>
<td>34%</td>
</tr>
<tr>
<td>Māori</td>
<td>19%</td>
<td>35%</td>
<td>33%</td>
<td>13%</td>
</tr>
<tr>
<td>Pasifika</td>
<td>27%</td>
<td>36%</td>
<td>28%</td>
<td>0%</td>
</tr>
</tbody>
</table>

B) Percentage of students capable of solving problems at each successive level

Although Māori students do less well, on average, 46% of Māori students can solve Level 2 problems compared with an average of 52% for OECD countries. This six percentage point gap between Māori students and the average OECD student for problem-solving is smaller than in the other three domains. For example, in

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1 For notes on interpretation, see student profile on page 8.

2 Box C gives examples of Level 2 tasks, which require more than basic problem-solving skills.
mathematics, 46% of Māori students can complete medium-level tasks (at Level 3 out of 6 proficiency levels) but this is 11 percentage points below the OECD countries (57%). Overall, the average performance of Māori students (488) for problem-solving is only 12 score points below the OECD average (500) and is significantly above the average performance for all students in the United States (477). This finding suggests that some Māori students who perform relatively weakly in curriculum-related subjects may show greater promise in generic skills.

On the other hand, only 13 percent of Māori students can solve the most difficult problem-solving tasks at Level 3, well below the OECD average of 18% and barely one-third of the figure for Pākehā/European and Asian students in New Zealand (see Figure 4). For Pasifika students the gap is even larger. Two-thirds of all Pasifika students are basic problem-solvers at Level 1 or below, whereas two-thirds of all New Zealand students are at proficiency Level 2 or above.

It should be noted that although there is a greater risk of lower performance for Māori and Pasifika students, almost half of New Zealand students who are at proficiency level 1 or below in problem-solving are Pākehā/European, as this group is almost twice the size of the other three main ethnic groups. This fact should be considered when contemplating strategies to raise problem-solving skills, as it is not sufficient to focus only on those ethnic groups with greatest risk of low proficiency.

**Box C: Illustration of medium-level problem-solving proficiency in PISA**

Two-thirds of students in New Zealand are capable of solving Level 2 tasks or above, making them ‘reasoning, decision-making’ problem-solvers.

The following two tasks, which illustrate proficiency at Level 2, require students to solve problems in the ‘trouble-shooting’ category. To solve them they need to understand how a system works and consider how it will behave in different circumstances. They need to be able to handle several interconnected relationships at once.
IRRIGATION

Below is a diagram of a system of irrigation channels for watering sections of crops. The gates A to H can be opened and closed to let the water go where it is needed. When a gate is closed no water can pass through it.

This is a problem about finding a gate which is stuck closed, preventing water from flowing through the system of channels.

Figure 1: A system of irrigation channels

Michael notices that the water is not always going where it is supposed to.

He thinks that one of the gates is stuck closed, so that when it is switched to “open”, it does not open.

Question 1: IRRIGATION

Michael finds that, when the gates have the Table 1 settings, no water flows through, indicating that at least one of the gates set to “open” is stuck closed.

Decide for each problem case below whether the water will flow through all the way. Circle “Yes” or “No” in each case.

<table>
<thead>
<tr>
<th>Problem Case</th>
<th>Will water flow through all the way?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate A is stuck closed. All other gates are working properly as set in Table 1.</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Gate D is stuck closed. All other gates are working properly as set in Table 1.</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Gate F is stuck closed. All other gates are working properly as set in Table 1.</td>
<td>Yes / No</td>
</tr>
</tbody>
</table>

A correct answer of No, Yes, Yes is associated with a score of 544 points, at Level 2.
Problem-solving for tomorrow’s world

Question 2: IRRIGATION

Michael wants to be able to test whether gate D is stuck closed.

In the following table, show settings for the gates to test whether gate D is stuck closed when it is set to “open”.

Settings for gates (each one “open” or “closed”)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A correct answer must fulfil one of the following two conditions:

- A and E are not both closed. D must be open. H can be open only if water cannot get to it (e.g. the other gates are closed, preventing water from reaching H). Otherwise, H must be closed.
- H is closed, and all the other gates are open.

This is associated with a score of 532 points, at Level 2.

Differences in problem-solving performance by socio-economic status

Socio-economic background is a key factor associated with higher and lower student performance across countries, subject areas, and different assessments. In PISA this is measured using a single index, based on the highest International Socio-Economic Index of Occupational Status of the parents (ISEI); a proxy measure of the highest level of parental education, an index of the educational resources in the home, and the number of books at home1. The results show that there is a ‘social gradient’, where students from more advantaged socio-economic backgrounds perform better on average in both curriculum-based assessments and problem-solving.

Figure 5 shows the proficiency levels reached by different New Zealand students according to the ISEI. Students are ranked into four, roughly equal groups by ISEI. The results show that at each successively higher level of socio-economic status, there are more students at Level 3 and fewer at Level 1 and below in problem-solving proficiency. This confirms the overall picture of a socio-economic ‘gradient’.

However, as was noted in the case of Māori students earlier in this report, it would be wrong to portray students with low socio-economic status in New Zealand as being poor problem-solvers by international standards. The problem-solving performance of New Zealand students classified as ‘low’ socio-economic status and the ‘average’ OECD student is similar with 17% of students in each group below proficiency Level 1. At proficiency Level 3, the corresponding figures are 14% for New Zealand students and 18% for the OECD on average. Indeed, problem-solving is the only domain in which New Zealand students in the low ISEI group perform at about the same level as the OECD average, with mean scores of 493 and 500 respectively; a difference that is not statistically significant.

Nevertheless, social differences remain in New Zealand. Students whose parents are in high-status occupations are three times more likely to be ‘reflective, communicative’ problem-solvers at Level 3 than students at the

1 PISA index of economic, social and cultural status.
opposite end of the socio-economic spectrum (45% compared with 14%). Analysis by socio-economic status also shows that around two-thirds (67%) of students at Level 1 problem-solving proficiency or below, fall into the category of low to medium-low socio-economic background.

**Figure 5: Problem-solving proficiency profile by socio-economic status (ISEI)**

A) Student profile by highest level of problem-solving proficiency

<table>
<thead>
<tr>
<th></th>
<th>“Weak” problem solvers (Below level 1)</th>
<th>“Basic” problem solvers (Level 1)</th>
<th>“Reasoning” problem solvers (Level 2)</th>
<th>“Reflective” problem solvers (Level 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High SES</strong></td>
<td>4%</td>
<td>15%</td>
<td>35%</td>
<td>45%</td>
</tr>
<tr>
<td><strong>Medium-high SES</strong></td>
<td>7%</td>
<td>22%</td>
<td>40%</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Medium-low SES</strong></td>
<td>5%</td>
<td>56%</td>
<td>35%</td>
<td>24%</td>
</tr>
<tr>
<td><strong>Low SES</strong></td>
<td>17%</td>
<td>39%</td>
<td>34%</td>
<td>14%</td>
</tr>
</tbody>
</table>

B) Percentage of students capable of solving problems at each successive level

Notes: For technical notes on graphs and figures, see Figure 1 on page 8. For definition of SES, see text.
Differences in problem-solving proficiency by school attended

The problem-solving performance of students varies across schools, and this can be partly attributed to the different socio-economic mix of students at different schools. The PISA 2003 Mathematics report points out that New Zealand, like the majority of countries participating in PISA, has more variation in performance between students within the same school, than between students in different schools, but socio-economic factors explain only a small part of the range of performance within schools. The level of within-school variance is relatively high in New Zealand compared with other OECD countries. However, this is likely to be related in part to the New Zealand secondary school system, which is non-selective in that students are not grouped into different schools according to academic ability. In countries where there is a substantial variation in performance between schools and less variation within schools, students tend to be grouped in schools in which other students perform at levels similar to their own.

Another way of looking at performance by schools is to use decile ranking. New Zealand schools are ranked into 10 percent groups roughly equal in number, which are called deciles. The Ministry of Education allocates funding to state and state-integrated schools based on their decile ranking. Decile 1 schools are the 10 percent of schools with the highest proportion of students from socio-economically disadvantaged communities, while Decile 10 schools are the 10 percent of schools with students from the lowest level of socio-economically disadvantaged communities. A school’s decile does not necessarily reflect the overall socio-economic mix of students attending the school.

Figure 6 shows the distribution of problem-solving proficiency in three decile groupings; Low (Deciles 1 to 3), Medium (Deciles 4 to 6) and High (Deciles 7 to 10). These groupings are not equal in size; the low-decile school group is 30% of all schools but has only 17% of the total student population. Students who attend low-decile schools are much more likely to be at Level 1 Proficiency or below (33%), compared with only 6% of students in high-decile schools. At the other end of the scale, only 1% of students attending low-decile schools reach Level 6 Proficiency in science, compared to 11% in high-decile schools.

Students attending high-decile schools are likely to be stronger in problem-solving than students in low-decile schools. As Figure 6 illustrates, 22% of students in low-decile schools are weak problem-solvers who cannot perform Level 1 Proficiency tasks. In contrast, only 4 percent of students in high-decile schools fall below Level 1. At the upper end, 40% of students in high-decile schools on average can be described as ‘reflective, communicative problem-solvers’ at Level 3 Proficiency, compared with 10% of students in low-decile schools.

Students in low-decile schools have a 59% chance of being at Level 1 Proficiency or below in problem-solving. This compares with 36% for New Zealand students as a whole. However, because relatively few New Zealand students are enrolled in low-decile schools, these students comprise only just over a quarter (28%) of the low-proficiency students in New Zealand. Efforts to raise problem-solving performance above a basic level should not concentrate only on these schools.

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1 Ethnicity was also a factor in the calculation of deciles in 2003.
Figure 6: Problem-solving proficiency profile by school decile grouping

A) Profile of students by their highest level of problem-solving proficiency

<table>
<thead>
<tr>
<th></th>
<th>“Weak” problem solvers (Below level 1)</th>
<th>“Basic” problem solvers (Level 1)</th>
<th>“Reasoning” problem solvers (Level 2)</th>
<th>“Reflective” problem solvers (Level 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High decile schools</td>
<td>4%</td>
<td>16%</td>
<td>38%</td>
<td>40%</td>
</tr>
<tr>
<td>Medium decile schools</td>
<td>10%</td>
<td>27%</td>
<td>37%</td>
<td>25%</td>
</tr>
<tr>
<td>Low decile schools</td>
<td>22%</td>
<td>57%</td>
<td>30%</td>
<td>10%</td>
</tr>
</tbody>
</table>

B) Percentage of students capable of solving problems at each successive level

Notes: For technical notes on graphs and figures, see Figure 1 on page 8. For definitions of school decile groupings, see text.
Conclusion

The assessment of problem-solving in PISA 2003 starts to address an important gap in international assessments as it not only looks at skills related to school curricula but also at important life skills that cross curriculum boundaries. Problem-solving ability is an important generic skill for life. It is also an important cognitive skill that influences performance in other areas, including mathematics.

In general, the results of the problem-solving assessment mirror the results in other domains. In New Zealand, there are strong correlations between student performance in problem-solving and their performance in reading, mathematics, and science. However, some important differences were identified:

- The range of average student scores in problem-solving is narrower than for the other domains of mathematics, science and reading.
- There is no difference between the performance of boys and girls in problem-solving.
- Students in New Zealand are somewhat stronger, relative to other countries, in problem-solving than in other domains. This strength is associated in particular with the better relative performance of the students towards the bottom end of the distribution.
- Low-achieving groups of New Zealand students, for example Māori and students from low socio-economic backgrounds, perform at a similar level to the OECD average in problem-solving.
- On the whole, differences between various sub-groups of the New Zealand student population appear to be less marked than in the curriculum-related domains assessed by PISA.

These findings suggest that some students in New Zealand are showing potential in problem-solving that is not being fully realised in equivalent performances in mathematics or other areas assessed by PISA. This raises an important issue for further investigation in relation to the delivery of the school curriculum. This is a positive finding for New Zealand in the sense that it indicates that most 15-year-olds have cognitive skills that allow them to solve at least basic problems and shows there is potential for improving other learning outcomes.
Appendix A: The problem-solving proficiency levels - further detail

**Level 3: Reflective, communicative problem-solvers**

Students proficient at Level 3 score above 592 points on the PISA problem-solving scale and are typically able to analyse a situation and make decisions and also think about the underlying relationships in a problem and relate these to the solution. Students at Level 3 approach problems systematically, construct their own representations to help them solve them, and verify that their solution satisfies all the requirements of the problem. These students communicate their solutions to others using accurate written statements and other representations.

Students at Level 3 tend to consider and deal with a large number of conditions, such as monitoring variables, accounting for temporal restrictions and other constraints. Problems at this level are demanding and require students to regulate their work and students at the top of Level 3 can cope with multiple interrelated conditions, requiring them to work back and forth between their solution and the conditions laid out in the problem. They can organise and monitor their thinking while working out their solution; problems at this level are often multifaceted, requiring students to manage all interactions simultaneously and develop a unique solution. Therefore, students at Level 3 are able to address these problems successfully and communicate their solutions clearly.

Students at Level 3 are also expected to be able to successfully complete the tasks located at the lower levels of the PISA problem-solving scale.

**Level 2: Reasoning, decision-making problem-solvers**

Students proficient at Level 2 score from 499 to 592 points on the problem-solving scale and use reasoning and analytical processes and solve problems requiring decision-making skills. These students can apply various types of reasoning (inductive and deductive reasoning, reasoning about causes and effects, or reasoning with many combinations). This involves systematically comparing all possible variations in well-described situations to analyse situations and to solve problems that require them to make a decision among well-defined alternatives. To analyse a system or make decisions, students at Level 2 combine and synthesise information from a variety of sources. They are able to combine various forms of representations (e.g. a formalised language, numerical information, and graphical information), handle unfamiliar representations (e.g., statements in a programming language or flow diagrams related to a mechanical or structural arrangement of components) and draw inferences based on two or more sources of information.

Students at Level 2 are also expected to be able to successfully complete tasks located at Level 1 of the PISA problem-solving scale.

**Level 1: Basic problem-solvers**

Students proficient at Level 1 score from 405 to 499 points on the problem-solving scale and typically solve problems where they have to deal with only a single data source containing discrete, well-defined information. They understand the nature of a problem and consistently locate and retrieve information related to the major features of the problem. Students at Level 1 are able to transform the information in the problem to present the problem differently, e.g. take information from a table to create a drawing or graph. Also, these students can apply information to check a limited number of well-defined conditions within the problem. However, they do not typically deal successfully with multifaceted problems involving more than one data source, or requiring them to reason with the information provided.
Below Level 1: Weak or emergent problem-solvers
The PISA problem-solving assessment was not designed to assess elementary problem-solving processes. As such, the assessment materials did not contain sufficient tasks to fully describe performances that fall below Level 1. Students with performances below Level 1 have scores of less than 405 points on the problem-solving scale and consistently fail to understand even the easiest items in the assessment, or fail to apply the necessary processes to characterise important features, or represent the problems. At most, they can deal with straightforward problems with carefully structured tasks that require the students to give responses based on facts, or to make observations with few or no inferences. Students below Level 1 have significant difficulties in making decisions, analysing or evaluating systems, and trouble-shooting situations.
## Appendix B: Features of the three types of problem-solving

<table>
<thead>
<tr>
<th></th>
<th>Decision-making</th>
<th>System analysis and design</th>
<th>Trouble-shooting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goals</strong></td>
<td>Choosing from alternatives under constraints</td>
<td>Identifying the relationships between parts of a system and/or designing a system to express the relationships between parts</td>
<td>Diagnosing and correcting a faulty or underperforming system or mechanism</td>
</tr>
<tr>
<td><strong>Processes involved</strong></td>
<td>Understanding a situation where there are several alternatives, constraints for a specified task</td>
<td>Understanding the information that characterises a given system and the requirements associated with a specified task</td>
<td>Understanding the main features of a system or mechanism and its malfunctioning as well as the demands of a specific task</td>
</tr>
<tr>
<td></td>
<td>Identifying relevant constraints</td>
<td>Identifying relevant parts of the system</td>
<td>Identifying causally related variables</td>
</tr>
<tr>
<td></td>
<td>Representing the possible alternatives</td>
<td>Representing the relationships among parts of the system</td>
<td>Representing the functioning of the system</td>
</tr>
<tr>
<td></td>
<td>Making a decision among alternatives</td>
<td>Analysing or designing a system that captures the relationships between parts</td>
<td>Diagnosing the malfunctioning of the system and/or proposing a solution</td>
</tr>
<tr>
<td></td>
<td>Checking and evaluating the decision</td>
<td>Checking and evaluating the analysis or the design of the system</td>
<td>Checking and evaluating the diagnosis/solution</td>
</tr>
<tr>
<td></td>
<td>Communicating or justifying the decision</td>
<td>Communicating the analysis or justifying the proposed design</td>
<td>Communicating or justifying the diagnosis and the solution</td>
</tr>
<tr>
<td><strong>Possible sources of complexity</strong></td>
<td>Number of constraints</td>
<td>Number of interrelated variables and nature of relationships</td>
<td>Number of interrelated parts of the system or mechanism and the ways in which these parts interact</td>
</tr>
<tr>
<td></td>
<td>Number and type of representations used (verbal, pictorial, and numerical)</td>
<td>Number and type of representations used (verbal, pictorial, and numerical)</td>
<td>Number and type of representations used (verbal, pictorial, and numerical)</td>
</tr>
</tbody>
</table>
Administration of PISA 2003

The Australian Council for Educational Research (ACER) led the PISA Consortium which managed the international coordination of the project. Other partners in this consortium include:

- The Netherlands National Institute for Educational Measurement (Citogroep);
- The National Institute for Educational Research in Japan (NIER);
- The Educational Testing Service in the United States (ETS); and
- WESTAT in the United States.

The Comparative Education Research Unit was responsible for carrying out the PISA activities in New Zealand. This Unit is located within the Research Division of the Ministry of Education.

Sources for this summary


For further information in New Zealand

Enquiries about this project may be directed to the:

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Research Division
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EMAIL: research.info@minedu.govt.nz
or PHONE: 0800 846 777
or FAX: 64-4-463-8312