3

# A Profile of Student Performance in Mathematics and Science

What can 15-year-old students do in mathematics and science? This chapter examines student performance in these two subjects as measured by PISA 2009. It provides examples of assessment questions, relating them to each PISA proficiency level, discusses gender differences in student performance, and compares countries' mean performance. As the global demand for highly skilled workers grows, the chapter also highlights today's top performers in reading, mathematics and science.

## WHAT STUDENTS CAN DO IN MATHEMATICS

PISA defines *mathematical literacy* as an individual's capacity to formulate, employ and interpret mathematics in a variety of contexts. This includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. *Mathematical literacy* also helps individuals recognise the role that mathematics plays in the world and make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens. In the PISA assessments, *mathematical literacy* is demonstrated through students' ability to analyse, reason and communicate effectively as they pose, solve and interpret mathematical problems that involve quantitative, spatial, probabilistic or other mathematical concepts.

Mathematics was the focus of the PISA 2003 survey, and the mean score on the PISA 2003 mathematics scale was set at 500 for OECD countries at that point. This mean score is the benchmark against which mathematics performances in PISA 2006 and PISA 2009 are compared. In PISA 2009, mathematics was given a smaller amount of assessment time than in PISA 2003. Ninety minutes of the assessment time were devoted to mathematics in 2009, allowing for only an update on overall performance rather than the kind of in-depth analysis of knowledge and skills shown in the PISA 2003 report (OECD, 2004).

### A profile of PISA mathematics questions

A selection of sample questions is included in the following section to illustrate the type of tasks students encounter in the PISA mathematics assessment. Each task presented includes the text, as seen by the students. The sample questions described here were released following the implementation of the PISA 2003 survey. A map of these selected questions is shown below in Figure I.3.1. The selected questions have been ordered according to their difficulty, with the most difficult at the top, and the least difficult at the bottom.

■ Figure I.3.1 ■

**Map of selected mathematics questions in PISA 2009, illustrating the proficiency levels**

| Level | Lower score limit | Questions |
|---|---|---|
| 6 | 669 | *CARPENTER* – Question 1 (687) |
| 5 | 607 | *TEST SCORES* – Question 16 (620) |
| 4 | 545 | *EXCHANGE RATE* – Question 11 (586) |
| 3 | 482 | *GROWING UP* – Question 7 (525) |
| 2 | 420 | *STAIRCASE* – Question 2 (421) |
| 1 | 358 | *EXCHANGE RATE* – Question 9 (406) |

Towards the top of the scale, the tasks typically involve a number of different elements, and require high levels of interpretation. Usually, the situations described are unfamiliar and so require some degree of thoughtful reflection and creativity. Questions generally demand some form of argument, often in the form of an explanation. Typical activities involved include: interpreting complex and unfamiliar data; imposing a mathematical construction on a complex real-world situation; and using mathematical modelling processes. At this level of the scale, questions tend to have several elements that need to be linked by students, and successful negotiation typically requires a strategic approach to several interrelated steps. For example, Question 1 from *CARPENTER* (Figure I.3.2) presents students with four diagrams and the students have to ascertain which of these (there could be more than one) would be suitable for a garden bed, given a certain length of timber for the perimeter. The question requires geometrical understanding and application.

Around the middle of the scale, questions require substantial interpretation, frequently of situations that are relatively unfamiliar or unpractised. Students may be required to restate the situation, often in more formal mathematical representations, in order to understand and analyse it. This often involves a chain of reasoning or a sequence of calculations. Students may also be required to express their reasoning through a simple explanation. Typical

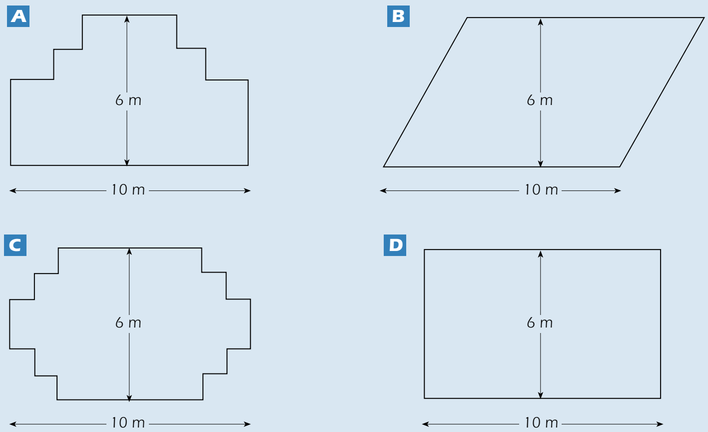
activities include: interpreting a set of related graphs; interpreting text, relating this to information in a table or graph, extracting the relevant information and performing some calculations; using scale conversions to calculate distances on a map; and using spatial reasoning and geometric knowledge to perform distance, speed and time calculations. For example, *GROWING UP* presents students with a graph of the average height of young males and young females from the ages of 10 to 20 years. Question 7 from *GROWING UP* (Figure I.3.5) asks students to identify the period of time when females are on average taller than males of the same age. Students must interpret the graph to understand exactly what is being displayed. They also have to relate the graphs for males and females to each other and determine how the specified period of time is shown, then accurately read the relevant values from the horizontal scale.

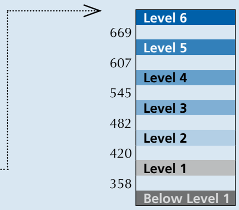
Near the bottom of the scale, questions set in simple and relatively familiar contexts require only the most limited interpretation of a situation and direct application of well-known mathematical concepts. Typical activities include: reading a value directly from a graph or table; performing a very simple and straightforward arithmetic calculation; ordering a small set of numbers correctly; counting familiar objects; using a simple currency exchange rate; and identifying and listing simple combinatorial outcomes. For example, Question 9 from *EXCHANGE RATE* (Figure I.3.7) presents students with a simple rate for converting Singapore dollars (SGD) into South African rand (ZAR), namely 1 SGD = 4.2 ZAR. The question requires students to apply the rate to convert 3000 SGD into ZAR. The rate is presented in the form of a familiar equation, and the mathematical step required is direct and reasonably obvious.

■ Figure I.3.2 ■

**CARPENTER**

A carpenter has 32 metres of timber and wants to make a border around a garden bed. He is considering the following designs for the garden bed.




**CARPENTER** – *QUESTION 1*

***Content area:*** *Space and shape*
***Difficulty:*** *687*
***Percentage of correct answers (OECD countries): 20.2%***

Circle either "Yes" or "No" for each design to indicate whether the garden bed can be made with 32 metres of timber.

| Garden bed design | Using this design, can the garden bed be made with 32 metres of timber? |
|---|---|
| Design A | Yes / No |
| Design B | Yes / No |
| Design C | Yes / No |
| Design D | Yes / No |

***Scoring***

**Full Credit:** Yes, No, Yes, Yes, in that order.

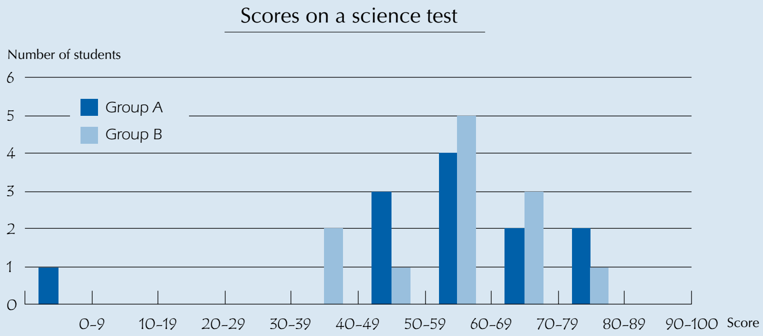
***Comment***

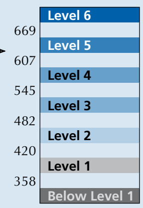
*This complex multiple-choice item is situated in an* educational *context, since it is the kind of quasi-realistic problem that would typically be seen in a mathematics class, rather than being a genuine problem likely to be met in an* occupational *setting. A small number of such problems have been included in PISA, though they are not typical. That being said, the competencies needed for this problem are certainly relevant and part of* mathematical literacy*. This item illustrates Level 6 with a difficulty of 687 score points. The item belongs to the* space and shape *content area. The students need the competence to recognise that the two-dimensional shapes A, C and D have the same perimeter, and therefore they need to decode the visual information and see similarities and differences. The students need to see whether or not a certain border-shape can be made with 32 metres of timber. In three cases this is rather evident because of the rectangular shapes. But the fourth is a parallelogram, requiring more than 32 metres. This use of geometrical insight, argumentation skills and some technical geometrical knowledge puts this item at Level 6.*

■ Figure I.3.3 ■

**TEST SCORES**

The diagram shows the results on a science test for two groups, labelled as Group A and Group B. The mean score for Group A is 62.0 and the mean for Group B is 64.5. Students pass this test when their score is 50 or above.




**TEST SCORE** – *QUESTION 16*

***Content area:*** *Uncertainty*

***Difficulty:*** *620*

***Percentage of correct answers (OECD countries): 32.7%***

Looking at the diagram, the teacher claims that Group B did better than Group A in this test.

The students in Group A don't agree with their teacher. They try to convince the teacher that Group B may not necessarily have done better.

Give one mathematical argument, using the graph that the students in Group A could use.

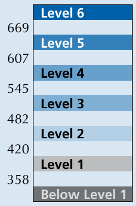
***Comment***

*This open-constructed response item is situated in an* educational *context. It has a difficulty of 620 score points. The* educational *context of this item is one that all students are familiar with: comparing test scores. In this case a science test has been administered to two groups of students: A and B. The results are given to the students in two different ways: in words with some data embedded and by means of two graphs in one grid. Students must find arguments that support the statement that Group A actually did better than Group B, given the counter-argument of one teacher that Group B did better – on the grounds of the higher mean for Group B. The item falls into the content area of uncertainty. Knowledge of this area of mathematics is essential, as data and graphical representations play a major role in the media and in other aspects of daily experiences. The students have a choice of at least three arguments here: the first one is that more students in Group A pass the test; a second one is the distorting effect of the outlier in the results of Group A; and a final argument is that Group A has more students that scored 80 or above. Students who are successful have applied statistical knowledge in a problem situation that is somewhat structured and where the mathematical representation is partially apparent. They need reasoning and insight to interpret and analyse the given information, and they must communicate their reasons and arguments. Therefore the item clearly illustrates Level 5.*

■ Figure I.3.4 ■

**EXCHANGE RATE – *Question 11***

Mei-Ling from Singapore was preparing to go to South Africa for 3 months as an exchange student. She needed to change some Singapore dollars (SGD) into South African rand (ZAR).




**EXCHANGE RATE** – *QUESTION 11*

***Content area:*** *Quantity*
***Difficulty:*** *586*
***Percentage of correct answers (OECD countries): 40.5%***

During these 3 months the exchange rate had changed from 4.2 to 4.0 ZAR per SGD.

Was it in Mei-Ling's favour that the exchange rate now was 4.0 ZAR instead of 4.2 ZAR, when she changed her South African rand back to Singapore dollars? Give an explanation to support your answer.

***Scoring***

**Full Credit:** Yes, with adequate explanation.

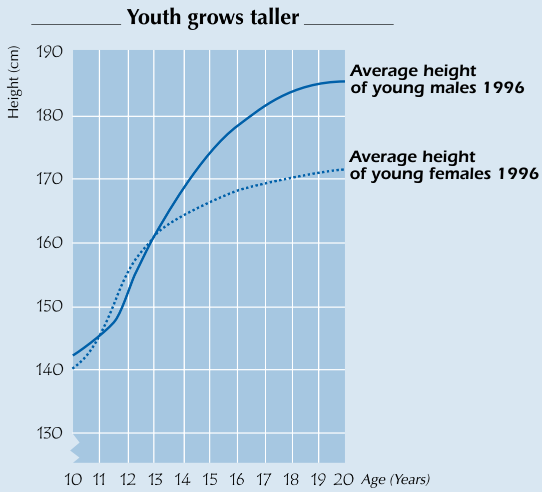
***Comment***

*This open-constructed response item is situated in a* public *context and has a difficulty of 586 score points. As far as the mathematics content is concerned students need to apply procedural knowledge involving number operations: multiplication and division, which along with the quantitative context, place the item in the* quantity *area. The competencies needed to solve the problem are not trivial. Students need to reflect on the concept of exchange rate and its consequences in this particular situation. The mathematisation required is of a rather high level, although all the required information is explicitly presented: not only is the identification of the relevant mathematics somewhat complex, but the reduction of it to a problem within the mathematical world also places significant demands on the student. The competency needed to solve this problem can be described as using flexible reasoning and reflection. Explaining the results requires some communication skills as well. The combination of familiar context, complex situation, non-routine problem and the need for reasoning, insight and communication places the item at Level 4.*

■ Figure I.3.5 ■

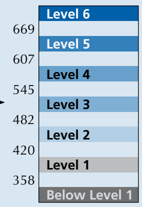
**GROWING UP**

In 1998 the average height of both young males and young females in the Netherlands is represented in this graph.




## GROWING UP – *QUESTION 7*

***Content area:*** *Change and relationships*
***Difficulty:*** *525*
***Percentage of correct answers (OECD countries): 54.8%***




According to this graph, on average, during which period in their life are females taller than males of the same age?

### *Scoring*

**Full Credit:** Responses giving the correct interval (from 11 to 13 years) or stating that girls are taller than boys when they are 11 and 12 years old.

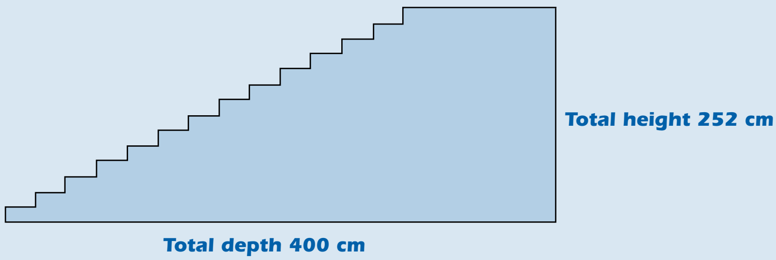
### *Comment*

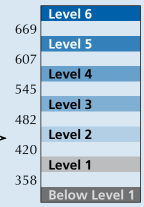
*This item, with its focus on age and height, lies in the* change and relationships *content area, and has a difficulty of 420 (Level 1). The students are asked to compare characteristics of two datasets, interpret these datasets and draw conclusions. The competencies needed to successfully solve the problem involve the interpretation and decoding of reasonably familiar and standard representations of well-known mathematical objects. Students need thinking and reasoning competencies to answer the question: "Where do the graphs have common points?" and argumentation and communication competencies to explain the role these points play in finding the desired answer. Students who score partial credit are able to show well-directed reasoning and/or insight, but they fail to come up with a full, comprehensive answer. They properly identify ages 11 and/or 12 and/or 13 as being part of an answer but fail to identify the continuum from 11 to 13 years. The item provides a good illustration of the boundary between Level 1 and Level 2. The full credit response to this item illustrates Level 3, as it has a difficulty of 525 score points. Students who score full credit not only show well-directed reasoning and/or insight, but they also come up with a full, comprehensive answer. Students who solve the problem successfully are adept at using graphical representations, making conclusions and communicating their findings.*

■ Figure I.3.6 ■

## STAIRCASE

The diagram below illustrates a staircase with 14 steps and a total height of 252 cm:




**STAIRCASE** – *QUESTION 2*

***Content area:*** *Space and shape*
***Difficulty:*** *421*
***Percentage of correct answers (OECD countries): 78.3%***

What is the height of each of the 14 steps?

Height: ..................cm.

### *Scoring*

**Full Credit:** 18

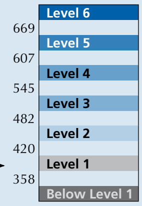
### *Comment*

*This short open-constructed response item is situated in a daily life context for carpenters and is therefore classified as having an* occupational *context. It has a difficulty of 421 score points. One does not need to be a carpenter to understand the relevant information; it is clear that an informed citizen should be able to interpret and solve a problem like this that uses two different representation modes: language, including numbers, and a graphical representation. But the illustration serves a simple and non-essential function: students know what stairs look like. This item is noteworthy because it has redundant information (the height is 252 cm) that is sometimes considered to be confusing by students; but such redundancy is common in real-world problem solving. The context of the stairs places the item in the* space and shape *content area, but the actual procedure to carry out is simple division. All the required information, and even more than that, is presented in a recognisable situation, and the students can extract the relevant information from a single source. In essence, the item makes use of a single representational mode, and with the application of a basic algorithm, this item fits, although barely, at Level 2.*

■ Figure I.3.7 ■

**EXCHANGE RATE – *Question 9***

Mei-Ling from Singapore was preparing to go to South Africa for 3 months as an exchange student. She needed to change some Singapore dollars (SGD) into South African rand (ZAR).




## EXCHANGE RATE – *QUESTION 9*

***Content area:*** *Quantity*
***Difficulty:*** *406*
***Percentage of correct answers (OECD countries): 79.9%***

Mei-Ling found out that the exchange rate between Singapore dollars and South African rand was:
1 SGD = 4.2 ZAR

Mei-Ling changed 3000 Singapore dollars into South African rand at this exchange rate.

How much money in South African rand did Mei-Ling get?

### *Scoring*

**Full Credit:** 12 600 ZAR (unit not required).

### *Comment*

*This short open-constructed response item is situated in a* public *context. It has a difficulty of 406 score points. Experience in using exchange rates may not be common to all students, but the concept can be seen as belonging to skills and knowledge for citizenship. The mathematics content is restricted to just one of the four basic operations: multiplication. This places the item in the* quantity *area, and more specifically, in operations with numbers. As far as the competencies are concerned, a very limited form of mathematisation is needed for understanding a simple text and linking the given information to the required calculation. All the required information is explicitly presented. Thus the competency needed to solve this problem can be described as the performance of a routine procedure and/or application of a standard algorithm. The combination of a familiar context, a clearly defined question and a routine procedure places the item at Level 1.*

## STUDENT PERFORMANCE IN MATHEMATICS

The six proficiency levels used in mathematics in the PISA 2009 assessment are the same as those established for mathematics in 2003 when it was the major area of assessment. The process used to produce proficiency levels in mathematics is similar to that used to produce proficiency levels in reading, as described in Volume I, Chapter 2.

■ Figure I.3.8 ■

**Summary descriptions for the six levels of proficiency in mathematics**

| Level | Lower score limit | What students can typically do |
|---|---|---|
| 6 | 669 | At Level 6 students can conceptualise, generalise and utilise information based on their investigations and modelling of complex problem situations. They can link different information sources and representations and flexibly translate between them. Students at this level are capable of advanced mathematical thinking and reasoning. These students can apply this insight and understanding along with a mastery of symbolic and formal mathematical operations and relationships to develop new approaches and strategies for attacking novel situations. Students at this level can formulate and precisely communicate their actions and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situations. |
| 5 | 607 | At Level 5 students can develop and work with models for complex situations, identifying constraints and specifying assumptions. They can select, compare, and evaluate appropriate problem-solving strategies for dealing with complex problems related to these models. Students at this level can work strategically using broad, well-developed thinking and reasoning skills, appropriately linked representations, symbolic and formal characterisations, and insight pertaining to these situations. They can reflect on their actions and formulate and communicate their interpretations and reasoning. |
| 4 | 545 | At Level 4 students can work effectively with explicit models for complex concrete situations that may involve constraints or call for making assumptions. They can select and integrate different representations, including symbolic representations, linking them directly to aspects of real-world situations. Students at this level can utilise well-developed skills and reason flexibly, with some insight, in these contexts. They can construct and communicate explanations and arguments based on their interpretations, arguments and actions. |
| 3 | 482 | At Level 3 students can execute clearly described procedures, including those that require sequential decisions. They can select and apply simple problem-solving strategies. Students at this level can interpret and use representations based on different information sources and reason directly from them. They can develop short communications reporting their interpretations, results and reasoning. |
| 2 | 420 | At Level 2 students can interpret and recognise situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures, or conventions. They are capable of direct reasoning and literal interpretations of the results. |
| 1 | 358 | At Level 1 students can answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. They are able to identify information and to carry out routine procedures according to direct instructions in explicit situations. They can perform actions that are obvious and follow immediately from the given stimuli. |

#### *Proficiency at Level 6 (scores higher than 669 points)*

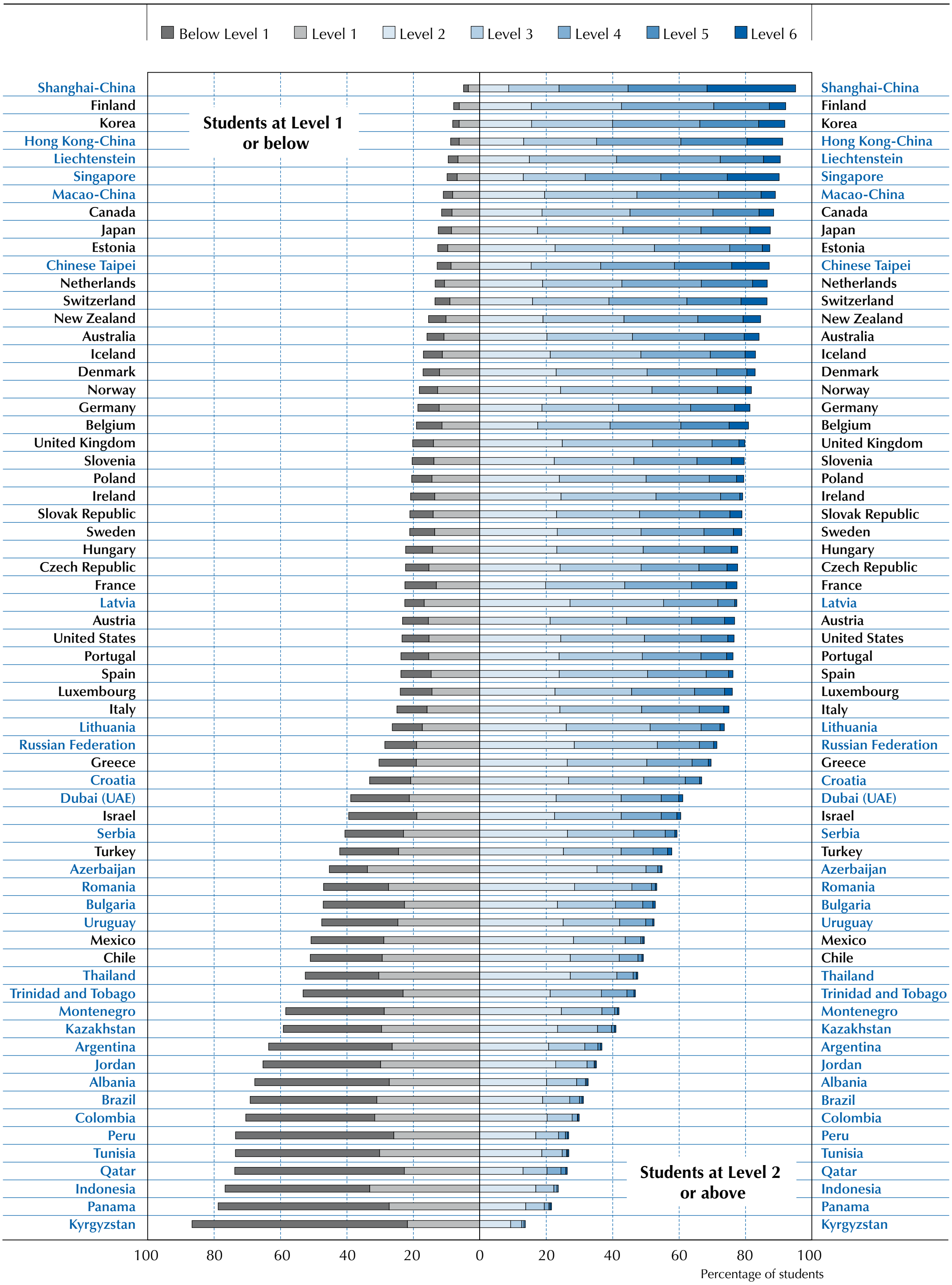
Students proficient at Level 6 on the mathematics scale can conceptualise, generalise, and utilise information based on their investigations and modelling of complex problem situations. They can link different information sources and representations and flexibly translate them. They are capable of advanced mathematical thinking and reasoning. These students can apply insight and understanding, along with a mastery of symbolic and formal mathematical operations and relationships, to develop new approaches and strategies for addressing novel situations. Students at this level can formulate and accurately communicate their actions and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the given situations.

Across OECD countries, an average of 3.1% of students perform at Level 6 in mathematics. In Korea and Switzerland, around 8% of students are at this level, and more than 5% of students in Japan, Belgium and New Zealand perform at this level. Among the partner countries and economies, in Shanghai-China, more than one-quarter of students perform at Level 6, while in Singapore, Chinese Taipei and Hong Kong-China the proportion is 15.6%, 11.3% and 10.8%, respectively. In contrast, less than 1% of students in Mexico, Chile, Greece and Ireland reach Level 6, and in the partner countries Kyrgyzstan, Indonesia, Colombia, Jordan, Albania, Tunisia and Panama, the percentage is close to zero.

■ Figure I.3.9 ■

**How proficient are students in mathematics?**

*Percentage of students at the different levels of mathematics proficiency*




*Countries are ranked in descending order of the percentage of students at Levels 2, 3, 4, 5 and 6.*
Source: OECD, *PISA 2009 Database*, Table I.3.1.

StatLink http://dx.doi.org/10.1787/888932343152

***Proficiency at Level 5 (scores higher than 607 but lower than or equal to 669 points)***

Students proficient at Level 5 can develop and work with models in complex situations, identifying constraints and specifying assumptions. They can select, compare, and evaluate appropriate problem-solving strategies for dealing with complex problems related to these models. Students at this level can work strategically using broad, well-developed thinking and reasoning skills, appropriately linked representations, symbolic and formal characterisations, and insight pertaining to these situations.

Across OECD countries, an average of 12.7% of students are proficient at Level 5 or higher (Figure I.3.9 and Table I.3.1). Korea is the OECD country with the highest percentage of students – 25.6% – at Level 5 or 6. Switzerland, Finland, Japan and Belgium have more than 20% of students at these levels, while in the partner countries and economies Singapore, Hong Kong-China and Chinese Taipei, the percentage of students at these levels is 35.6%, 30.7% and 28.6%, respectively, and in Shanghai-China, more than half of all students perform at least at Level 5. With the exception of Chile and Mexico, more than 5% of students in every OECD country reach at least Level 5.

***Proficiency at Level 4 (scores higher than 545 but lower than or equal to 607 points)***

Students proficient at Level 4 can work effectively with explicit models for complex concrete situations that may involve constraints or call for making assumptions. They can select and integrate different representations, including symbolic representations, and link them directly to aspects of real-world situations. Students at this level can use well-developed skills and reason flexibly, with some insight, in these contexts.

Across OECD countries, an average of 31.6% of students are proficient at Level 4 or higher (that is, at Level 4, 5 or 6) (Figure I.3.9 and Table I.3.1). In Korea and the partner countries and economies Shanghai-China, Singapore, Hong Kong-China and Chinese Taipei, the majority of students perform at this level. In Finland, Switzerland, Japan, the Netherlands, Canada, Belgium, and New Zealand, and the partner countries and economies Liechtenstein and Macao-China, more than 40% do so. However, in Mexico, Chile, Turkey, Israel and Greece, and in the majority of the partner countries and economies, less than one-quarter of students attain at least Level 4.

***Proficiency at Level 3 (scores higher than 482 but lower than or equal to 545 points)***

Students proficient at Level 3 can execute clearly described procedures, including those that require sequential decisions. They can select and apply simple problem-solving strategies and can interpret and use representations based on different information sources. They can communicate their interpretations, results and reasoning succinctly.

Across OECD countries, an average of 56.0% of students are proficient at Level 3 or higher (that is, at Level 3, 4, 5 or 6) (Figure I.3.9 and Table I.3.1). In the OECD countries Finland and Korea, and the partner countries and economies Shanghai-China, Hong Kong-China, Singapore and Liechtenstein, over three-quarters of 15-year-olds are proficient at Level 3 or higher, and at least two-thirds of students attain this level in the OECD countries Switzerland, Japan, Canada and the Netherlands and the partner economies Chinese Taipei and Macao-China.

***Proficiency at Level 2 (scores higher than 420 but lower than or equal to 482 points)***

Students proficient at Level 2 can interpret and recognise situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures or conventions. They are capable of direct reasoning and making literal interpretations of the results. Level 2 represents a baseline level of mathematics proficiency on the PISA scale at which students begin to demonstrate the kind of skills that enable them to use mathematics in ways that are considered fundamental for their future development.

Across OECD countries, an average of 78.0% of students are proficient at Level 2 or higher. In Finland and Korea, and in the partner countries and economies Shanghai-China, Hong Kong-China, Liechtenstein and Singapore, more than 90% of students perform at or above this threshold. In every OECD country except Chile, Mexico, Turkey, Israel and Greece, at least three-quarters of students are at Level 2 or above, and in Chile and Mexico more than half of all students are below Level 2 (Figure I.3.9 and Table I.3.1).

***Proficiency at Level 1 (scores higher than 358 but lower than or equal to 420 points) or below***

Students proficient at Level 1 can answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. They are able to identify information and to carry out routine procedures according to direct instructions in explicit situations. They can perform obvious actions that follow immediately from the given stimuli.

Students performing below 358 score points – that is, below Level 1 – usually do not succeed at the most basic mathematical tasks that PISA measures. Their pattern of answers is such that they would be expected to solve fewer than half of the tasks in a test made up of questions drawn solely from Level 1. Such students are likely to have serious difficulties using mathematics to benefit from further education and learning opportunities throughout life.

Across OECD countries, an average of 14.0% of students perform at Level 1, and 8.0% perform below Level 1, but there are wide differences between countries. In Finland and Korea, and in the partner countries and economies Shanghai-China, Hong Kong-China, Liechtenstein and Singapore, less than 10% of students perform at or below Level 1. In all other OECD countries, the percentage of students performing at or below Level 1 ranges from 11.5% in Canada to 51.0% in Chile (Figure I.3.9 and Table I.3.1).

## Mean country performance in mathematics

The discussion above has focused on comparisons of the distributions of student performance between countries. Another way to summarise student performance and to compare the relative standing of countries in mathematics is by way of countries' mean scores on the PISA assessment. Countries with high average performance will have a considerable economic and social advantage. As explained before, because mathematics was the focus of the PISA 2003 survey, the PISA 2003 mean score for OECD countries was set at 500. This score establishes the benchmark against which mathematics performance in PISA 2006 and PISA 2009 are compared. The average score in mathematics in PISA 2009 (496 score points) appears to be slightly lower than the score of 500 in PISA 2003, but this difference is not statistically significant.

When interpreting mean performance, only those differences between countries that are statistically significant should be taken into account. Figure I.3.10 shows each country's mean score and also for which pairs of countries the differences between the means shown are statistically significant. For each country shown on the left in the middle column, the list of countries in the right hand column shows countries whose mean scores are not statistically significantly different. For all other cases, one country has a higher performance than another if it is above it in the list in the middle column, and lower performance if it is below it. For example: Shanghai-China ranks first, Singapore second and Hong Kong-China third, but the performance of Korea, which appears fourth on the list, cannot be distinguished with confidence from that of Chinese Taipei.

Korea, with a country mean of 546 score points in mathematics, is the highest performing OECD country. Three partner countries and economies, Shanghai-China, Singapore and Hong Kong-China, have a mean score that is around one proficiency level or more above the average of 496 score points in PISA 2009. Other OECD countries with mean performances above the average include Finland (541), Switzerland (534), Japan (529), Canada (527), the Netherlands (526), New Zealand (519), Belgium (515), Australia (514), Germany (513), Estonia (512), Iceland (507), Denmark (503) and Slovenia (501). Three partner countries and economies perform above the average: Chinese Taipei (543), Liechtenstein (536) and Macao-China (525). Nine OECD countries perform around the average: Norway, France, the Slovak Republic, Austria, Poland, Sweden, the Czech Republic, the United Kingdom and Hungary.

Among OECD countries, performance differences are large; 128 score points separate the mean scores of the highest and lowest performing OECD countries, and when the partner countries and economies are considered along with the OECD countries, this range amounts to 269 score points.

Because the figures are derived from samples, it is not possible to determine a precise rank of the performance of a country among the participating countries. It is, however, possible to determine, with confidence, a range of ranks in which the country's performance level lies (Figure I.3.11).

The performance range between the highest- and lowest-performing students is shown in Table I.3.3. Finland, which is one of the highest-performing OECD countries, shows one of the narrowest distributions between the 5th percentile, the point on the PISA mathematics scale which the 5% lowest-performing students attain, and the 95th percentile, the point which 5% of the best-performing students attain, with a difference equivalent to 270 score points. Among the partner countries and economies, some of the lower-performing countries, such as Indonesia, Colombia and Tunisia, have a narrow distribution, ranging from 233 to 252 score points. Among the partner countries and economies, Singapore, Chinese Taipei and Shanghai-China have the largest differences in the performances of their students between the 5th and the 95th percentiles, but are among the 5 countries with the highest performance in mathematics. In the OECD area, Israel, Belgium, Switzerland, France, Luxembourg and Germany also show a wide performance range. In Israel and Belgium, this partly reflects the performance differences between different communities.

■ Figure I.3.10 ■

**Comparing countries' performance in mathematics**

- Statistically significantly **above** the OECD average
- Not statistically significantly different from the OECD average
- Statistically significantly **below** the OECD average

| Mean | Comparison country | Countries whose mean score is NOT statistically significantly different from that of the comparison country |
|---|---|---|
| 600 | Shanghai-China | |
| 562 | Singapore | |
| 555 | Hong Kong-China | Korea |
| 546 | Korea | Hong Kong-China, Chinese Taipei, Finland, Liechtenstein |
| 543 | Chinese Taipei | Korea, Finland, Liechtenstein, Switzerland |
| 541 | Finland | Korea, Chinese Taipei, Liechtenstein, Switzerland |
| 536 | Liechtenstein | Korea, Chinese Taipei, Finland, Switzerland, Japan, Netherlands |
| 534 | Switzerland | Chinese Taipei, Finland, Liechtenstein, Japan, Canada, Netherlands |
| 529 | Japan | Liechtenstein, Switzerland, Canada, Netherlands, Macao-China |
| 527 | Canada | Switzerland, Japan, Netherlands, Macao-China |
| 526 | Netherlands | Liechtenstein, Switzerland, Japan, Canada, Macao-China, New Zealand |
| 525 | Macao-China | Japan, Canada, Netherlands |
| 519 | New Zealand | Netherlands, Belgium, Australia, Germany |
| 515 | Belgium | New Zealand, Australia, Germany, Estonia |
| 514 | Australia | New Zealand, Belgium, Germany, Estonia |
| 513 | Germany | New Zealand, Belgium, Australia, Estonia, Iceland |
| 512 | Estonia | Belgium, Australia, Germany, Iceland |
| 507 | Iceland | Germany, Estonia, Denmark |
| 503 | Denmark | Iceland, Slovenia, Norway, France, Slovak Republic |
| 501 | Slovenia | Denmark, Norway, France, Slovak Republic, Austria |
| 498 | Norway | Denmark, Slovenia, France, Slovak Republic, Austria, Poland, Sweden, Czech Republic, United Kingdom, Hungary |
| 497 | France | Denmark, Slovenia, Norway, Slovak Republic, Austria, Poland, Sweden, Czech Republic, United Kingdom, Hungary |
| 497 | Slovak Republic | Denmark, Slovenia, Norway, France, Austria, Poland, Sweden, Czech Republic, United Kingdom, Hungary |
| 496 | Austria | Slovenia, Norway, France, Slovak Republic, Poland, Sweden, Czech Republic, United Kingdom, Hungary, United States |
| 495 | Poland | Norway, France, Slovak Republic, Austria, Sweden, Czech Republic, United Kingdom, Hungary, Luxembourg, United States, Portugal |
| 494 | Sweden | Norway, France, Slovak Republic, Austria, Poland, Czech Republic, United Kingdom, Hungary, Luxembourg, United States, Ireland, Portugal |
| 493 | Czech Republic | Norway, France, Slovak Republic, Austria, Poland, Sweden, United Kingdom, Hungary, Luxembourg, United States, Ireland, Portugal |
| 492 | United Kingdom | Norway, France, Slovak Republic, Austria, Poland, Sweden, Czech Republic, Hungary, Luxembourg, United States, Ireland, Portugal |
| 490 | Hungary | Norway, France, Slovak Republic, Austria, Poland, Sweden, Czech Republic, United Kingdom, Luxembourg, United States, Ireland, Portugal, Spain, Italy, Latvia |
| 489 | Luxembourg | Poland, Sweden, Czech Republic, United Kingdom, Hungary, United States, Ireland, Portugal |
| 487 | United States | Austria, Poland, Sweden, Czech Republic, United Kingdom, Hungary, Luxembourg, Ireland, Portugal, Spain, Italy, Latvia |
| 487 | Ireland | Sweden, Czech Republic, United Kingdom, Hungary, Luxembourg, United States, Portugal, Spain, Italy, Latvia |
| 487 | Portugal | Poland, Sweden, Czech Republic, United Kingdom, Hungary, Luxembourg, United States, Ireland, Spain, Italy, Latvia |
| 483 | Spain | Hungary, United States, Ireland, Portugal, Italy, Latvia |
| 483 | Italy | Hungary, United States, Ireland, Portugal, Spain, Latvia |
| 482 | Latvia | Hungary, United States, Ireland, Portugal, Spain, Italy, Lithuania |
| 477 | Lithuania | Latvia |
| 468 | Russian Federation | Greece, Croatia |
| 466 | Greece | Russian Federation, Croatia |
| 460 | Croatia | Russian Federation, Greece |
| 453 | Dubai (UAE) | Israel, Turkey |
| 447 | Israel | Dubai (UAE), Turkey, Serbia |
| 445 | Turkey | Dubai (UAE), Israel, Serbia |
| 442 | Serbia | Israel, Turkey |
| 431 | Azerbaijan | Bulgaria, Romania, Uruguay |
| 428 | Bulgaria | Azerbaijan, Romania, Uruguay, Chile, Thailand, Mexico |
| 427 | Romania | Azerbaijan, Bulgaria, Uruguay, Chile, Thailand |
| 427 | Uruguay | Azerbaijan, Bulgaria, Romania, Chile |
| 421 | Chile | Bulgaria, Romania, Uruguay, Thailand, Mexico |
| 419 | Thailand | Bulgaria, Romania, Chile, Mexico, Trinidad and Tobago |
| 419 | Mexico | Bulgaria, Chile, Thailand |
| 414 | Trinidad and Tobago | Thailand |
| 405 | Kazakhstan | Montenegro |
| 403 | Montenegro | Kazakhstan |
| 388 | Argentina | Jordan, Brazil, Colombia, Albania |
| 387 | Jordan | Argentina, Brazil, Colombia, Albania |
| 386 | Brazil | Argentina, Jordan, Colombia, Albania |
| 381 | Colombia | Argentina, Jordan, Brazil, Albania, Indonesia |
| 377 | Albania | Argentina, Jordan, Brazil, Colombia, Tunisia, Indonesia |
| 371 | Tunisia | Albania, Indonesia, Qatar, Peru, Panama |
| 371 | Indonesia | Colombia, Albania, Tunisia, Qatar, Peru, Panama |
| 368 | Qatar | Tunisia, Indonesia, Peru, Panama |
| 365 | Peru | Tunisia, Indonesia, Qatar, Panama |
| 360 | Panama | Tunisia, Indonesia, Qatar, Peru |
| 331 | Kyrgyzstan | |

Source: OECD, *PISA 2009 Database*.
StatLink http://dx.doi.org/10.1787/888932343152

■ Figure I.3.11 ■

## Where countries rank in mathematics performance

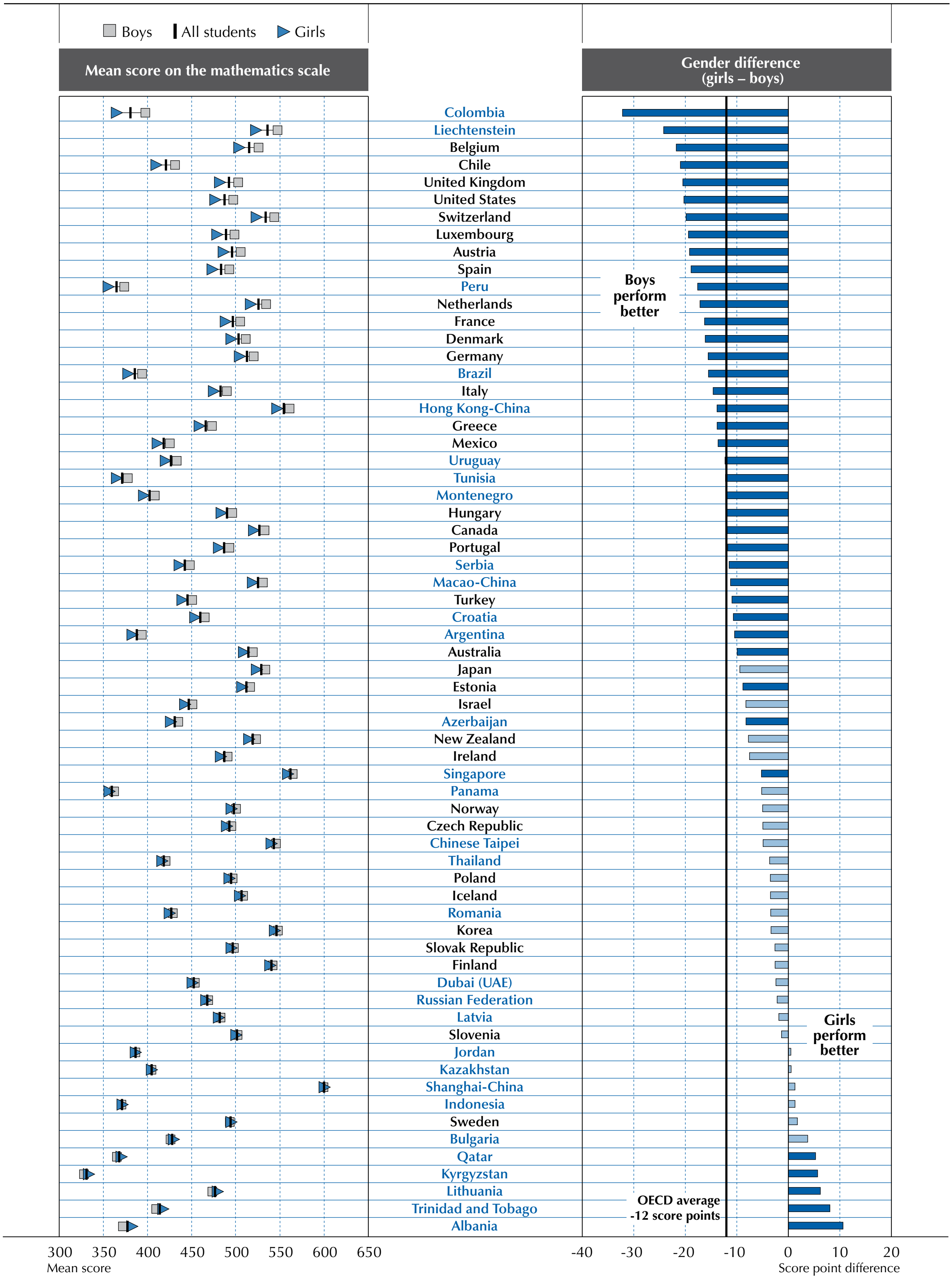
- Statistically significantly **above** the OECD average
- Not statistically significantly different from the OECD average
- Statistically significantly **below** the OECD average

| | Mathematics | | | | | |
|---|---|---|---|---|---|---|
| | | | Range of rank | | | |
| | | | OECD countries | | All countries/economies | |
| | Mean Score | S.E. | Upper rank | Lower rank | Upper rank | Lower rank |
| Shanghai-China | 600 | (2.8) | | | 1 | 1 |
| Singapore | 562 | (1.4) | | | 2 | 2 |
| Hong Kong-China | 555 | (2.7) | | | 3 | 4 |
| Korea | 546 | (4.0) | 1 | 2 | 3 | 6 |
| Chinese Taipei | 543 | (3.4) | | | 4 | 7 |
| Finland | 541 | (2.2) | 1 | 3 | 4 | 7 |
| Liechtenstein | 536 | (4.1) | | | 5 | 9 |
| Switzerland | 534 | (3.3) | 2 | 4 | 6 | 9 |
| Japan | 529 | (3.3) | 3 | 6 | 8 | 12 |
| Canada | 527 | (1.6) | 4 | 6 | 9 | 12 |
| Netherlands | 526 | (4.7) | 3 | 7 | 8 | 13 |
| Macao-China | 525 | (0.9) | | | 10 | 12 |
| New Zealand | 519 | (2.3) | 6 | 8 | 12 | 14 |
| Belgium | 515 | (2.3) | 7 | 11 | 13 | 17 |
| Australia | 514 | (2.5) | 7 | 11 | 13 | 17 |
| Germany | 513 | (2.9) | 8 | 12 | 13 | 17 |
| Estonia | 512 | (2.6) | 8 | 11 | 14 | 17 |
| Iceland | 507 | (1.4) | 11 | 13 | 17 | 19 |
| Denmark | 503 | (2.6) | 12 | 16 | 18 | 21 |
| Slovenia | 501 | (1.2) | 13 | 15 | 19 | 21 |
| Norway | 498 | (2.4) | 13 | 20 | 19 | 26 |
| France | 497 | (3.1) | 13 | 22 | 19 | 28 |
| Slovak Republic | 497 | (3.1) | 13 | 22 | 19 | 28 |
| Austria | 496 | (2.7) | 14 | 22 | 20 | 28 |
| Poland | 495 | (2.8) | 15 | 24 | 21 | 29 |
| Sweden | 494 | (2.9) | 15 | 24 | 21 | 30 |
| Czech Republic | 493 | (2.8) | 16 | 25 | 22 | 31 |
| United Kingdom | 492 | (2.4) | 17 | 25 | 23 | 31 |
| Hungary | 490 | (3.5) | 18 | 28 | 23 | 34 |
| Luxembourg | 489 | (1.2) | 22 | 26 | 28 | 33 |
| United States | 487 | (3.6) | 21 | 29 | 26 | 36 |
| Ireland | 487 | (2.5) | 22 | 29 | 28 | 35 |
| Portugal | 487 | (2.9) | 22 | 29 | 28 | 36 |
| Spain | 483 | (2.1) | 26 | 29 | 32 | 36 |
| Italy | 483 | (1.9) | 26 | 29 | 32 | 36 |
| Latvia | 482 | (3.1) | | | 32 | 37 |
| Lithuania | 477 | (2.6) | | | 36 | 38 |
| Russian Federation | 468 | (3.3) | | | 38 | 39 |
| Greece | 466 | (3.9) | 30 | 30 | 38 | 40 |
| Croatia | 460 | (3.1) | | | 39 | 40 |
| Dubai (UAE) | 453 | (1.1) | | | 41 | 42 |
| Israel | 447 | (3.3) | 31 | 32 | 42 | 44 |
| Turkey | 445 | (4.4) | 31 | 32 | 41 | 44 |
| Serbia | 442 | (2.9) | | | 42 | 44 |
| Azerbaijan | 431 | (2.8) | | | 45 | 47 |
| Bulgaria | 428 | (5.9) | | | 45 | 51 |
| Romania | 427 | (3.4) | | | 45 | 49 |
| Uruguay | 427 | (2.6) | | | 45 | 49 |
| Chile | 421 | (3.1) | 33 | 34 | 47 | 51 |
| Thailand | 419 | (3.2) | | | 48 | 52 |
| Mexico | 419 | (1.8) | 33 | 34 | 49 | 51 |
| Trinidad and Tobago | 414 | (1.3) | | | 51 | 52 |
| Kazakhstan | 405 | (3.0) | | | 53 | 54 |
| Montenegro | 403 | (2.0) | | | 53 | 54 |
| Argentina | 388 | (4.1) | | | 55 | 58 |
| Jordan | 387 | (3.7) | | | 55 | 58 |
| Brazil | 386 | (2.4) | | | 55 | 58 |
| Colombia | 381 | (3.2) | | | 56 | 59 |
| Albania | 377 | (4.0) | | | 57 | 61 |
| Tunisia | 371 | (3.0) | | | 59 | 63 |
| Indonesia | 371 | (3.7) | | | 59 | 63 |
| Qatar | 368 | (0.7) | | | 61 | 63 |
| Peru | 365 | (4.0) | | | 61 | 64 |
| Panama | 360 | (5.2) | | | 62 | 64 |
| Kyrgyzstan | 331 | (2.9) | | | 65 | 65 |

Source: OECD, *PISA 2009 Database*.
StatLink http://dx.doi.org/10.1787/888932343152

■ Figure I.3.12 ■

**Gender differences in mathematics performance**




Note: Statistically significant gender differences are marked in a darker tone (see Annex A3).
*Countries are ranked in ascending order of the gender score point difference (girls – boys).*
Source: OECD, *PISA 2009 Database*, Table I.3.3.
StatLink http://dx.doi.org/10.1787/888932343152

## Gender differences in mathematics

On average across OECD countries, boys outperformed girls, with an advantage of 12 score points.

Of all 65 participating countries there are 35 countries with an advantage for boys and 5 with an advantage for girls. For the countries with an advantage for boys on the mathematics scale, gender differences vary widely, even if they tend to be much smaller than corresponding gender differences observed on the reading scale. The largest gender differences are observed in Belgium, Chile, the United Kingdom and the United States, with an advantage of 20 score points or more for boys and a difference of 32 and 24 score points, respectively, in the partner countries and economies Colombia and Liechtenstein. Japan, New Zealand, Ireland, Norway, the Czech Republic, Poland, Iceland, Korea, the Slovak Republic, Finland, Slovenia and Sweden, as well as the partner countries and economies Panama, Chinese Taipei, Thailand, Romania, Dubai (UAE), the Russian Federation, Latvia, Jordan, Kazakhstan, Shanghai-China, Indonesia and Bulgaria do not show measurable differences between the scores for boys and girls. In the partner countries and economies Qatar, Kyrgyzstan, Lithuania, Trinidad and Tobago and Albania, girls outperformed boys in mathematics by between 5 and 11 score points (Table I.3.3).

## WHAT STUDENTS CAN DO IN SCIENCE

An understanding of science and technology is central to a young person's preparedness for life in modern society. This understanding also empowers individuals to participate in determining public policy where issues of science and technology affect their lives. PISA defines *scientific literacy* as an individual's scientific knowledge, and use of that knowledge, to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues; their understanding of the characteristic features of science as a form of human knowledge and enquiry; their awareness of how science and technology shape our material, intellectual and cultural environments; and their willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen.

PISA examines both the cognitive and affective aspects of students' competencies in science. The cognitive aspects include students' knowledge and capacity to use this knowledge effectively, as they carry out certain cognitive processes that are characteristic of science and scientific enquiries of personal, social, or global relevance. Science was the focus of the PISA 2006 survey, and the PISA 2006 science mean score for OECD countries was set at 498 then (500 in PISA 2006 with the 30 OECD countries, but 498 after taking into account the 4 new OECD countries). This mean score is the benchmark against which science performance in PISA 2009 is compared and will be the benchmark for such comparisons in the future. However, in PISA 2009, science was given a smaller amount of assessment time than in PISA 2006. Ninety minutes of the assessment time were devoted to science in 2009, allowing for only an update on overall performance rather than the kind of in-depth analysis of knowledge and skills shown in the PISA 2006 report (OECD, 2007). The average score in science in PISA 2009 is set at 501.

## A profile of PISA science questions

Figure I.3.13 shows a map of a selection of PISA science questions and scores (in parentheses) to illustrate broadly what is required at different difficulty levels. The sample questions described in the following section were released following the implementation of the PISA 2006 survey. The selected questions have been ordered according to their difficulty, with the most difficult at the top, and the least difficult at the bottom.

■ Figure I.3.13 ■

**Map of selected science questions in PISA 2009, illustrating the proficiency levels**

| Level | Lower score limit | Questions |
|---|---|---|
| 6 | 708 | *GREENHOUSE* – Question 5 (709) |
| 5 | 633 | *GREENHOUSE* – Question 4.2 (659) (full credit) |
| 4 | 559 | *CLOTHES* – Question 1 (567) |
| 3 | 484 | *MARY MONTAGU* – Question 4 (507) |
| 2 | 409 | *GENETICALLY MODIFIED CROPS* – Question 3 (421) |
| 1 | 335 | *PHYSICAL EXERCISE* – Question 3 (386) |

Factors that determine the difficulty of questions assessing science performance include: the level of familiarity of the scientific ideas, processes and terminology involved; the length of the train of logic required to respond to a question, that is, the number of steps needed to arrive at an adequate response and how much one step depends on the previous one; the degree to which abstract scientific ideas or concepts are required in forming a response; and the level of reasoning, insight and generalisation involved in forming judgements, conclusions and explanations.

Typical questions near the top of the scale involve interpreting complex and unfamiliar data, imposing a scientific explanation on a complex real-world situation, and applying scientific processes to unfamiliar problems. At this part of the scale, questions tend to have several scientific or technological elements that need to be linked by students, requiring several interrelated steps. The construction of evidence-based arguments also requires critical thinking and abstract reasoning. Question 5 from GREENHOUSE (Figure I.3.14) is an example of Level 6 and of the competency to explain phenomena scientifically. In this question, students must analyse a conclusion to account for other factors that could influence the greenhouse effect. As a first step to solving this problem, the student must be able to identify the change and measured variables and have sufficient understanding of the methods of investigation to recognise the influence of other factors. In addition, the student needs to recognise the scenario and identify its major components. This involves identifying a number of abstract concepts and their relationships in order to determine what "other" factors might affect the relationship between Earth's temperature and the amount of carbon dioxide emissions in the atmosphere. Thus, in order to respond correctly, a student must understand the need to control factors outside the changed and measured variables and must possess sufficient knowledge of "Earth systems" to identify at least one of the factors that should be controlled. Sufficient knowledge of "Earth systems" is considered the critical scientific skill involved, so this question is categorised as explaining phenomena scientifically.

Around the middle of the scale, questions require substantially more interpretation, frequently in situations that are relatively unfamiliar. Sometimes they demand the use of knowledge from different scientific disciplines, including more formal scientific or technological representation, and the thoughtful synthesis of those disciplines in order to promote understanding and facilitate analysis. Sometimes they involve a chain of reasoning and require students to express their reasoning in a simple explanation. Typical activities include interpreting aspects of a scientific investigation, explaining certain procedures used in an experiment and providing evidence-based reasons for a recommendation. An example of a question in the middle of the scale is Question 4 from MARY MONTAGU (Figure I.3.16). This question requires the student to identify why young children and old people are more at risk of the effects of influenza than others in the population. Directly, or by inference, the reason is attributed to the weaker immune systems among young children and old people. The issue is community control of disease, so the setting is social. A correct explanation involves applying several pieces of knowledge that are well established in the community. The question stem also provides a clue to the groups' different levels of resistance to disease.

On the bottom of the scale, questions require less scientific knowledge and are applied in familiar contexts, with easy scientific explanations that arise directly from given evidence. Question 3 of PHYSICAL EXERCISE (Figure I.3.18) is an example of an easy question, located at Level 1 on the PISA science scale below the baseline of *scientific literacy*. To gain credit, a student must recall knowledge about the operation of muscles and formation of fat in the body correctly, particularly the facts that when muscles are exercised they receive an increased flow of blood and fats are not formed. This knowledge enables students to accept the first statement of this complex multiple-choice question and reject the second one. In this question, no context needs to be analysed: the knowledge required has widespread currency and no relationships need to be investigated or established.

■ Figure I.3.14 ■
## GREENHOUSE

*Read the texts and answer the questions that follow.*

### THE GREENHOUSE EFFECT: FACT OR FICTION?

Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth.

The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world.

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

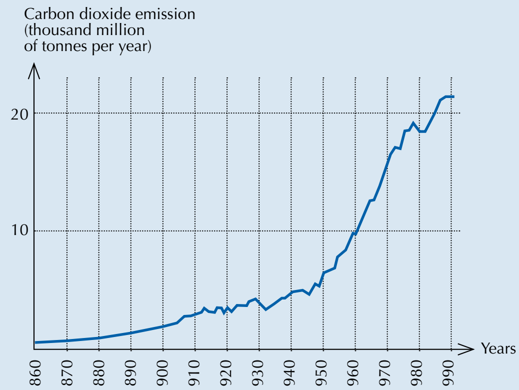
As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term greenhouse effect.

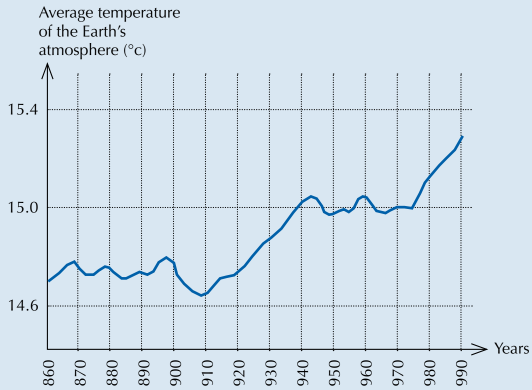
The greenhouse effect is said to have become more pronounced during the twentieth century.

It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

A student named André becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth.

In a library he comes across the following two graphs.

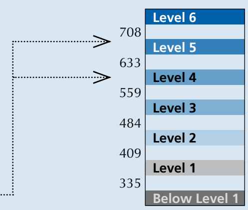



André concludes from these two graphs that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

**GREENHOUSE** – *QUESTION 4*

***Question type:*** *Open-constructed response*
***Competency:*** *Using scientific evidence*
***Knowledge category:*** *"Scientific explanations" (knowledge about science)*
***Application area:*** *"Environment"*
***Setting:*** *Global*
***Difficulty:*** *Full credit 659; Partial credit 568*
***Percentage of correct answers (OECD countries):*** *34 5%*




Another student, Jeanne, disagrees with André's conclusion. She compares the two graphs and says that some parts of the graphs do not support his conclusion.

Give an example of a part of the graphs that does not support André's conclusion. Explain your answer.

.................................................................................................................................................

.................................................................................................................................................

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### *Scoring*

**Full Credit:**

Refers to one particular part of the graphs in which the curves are not both descending or both climbing and gives the corresponding explanation. For example:

- In 1900–1910 (about) $CO_2$ was increasing, whilst the temperature was going down.
- In 1980–1983 carbon dioxide went down and the temperature rose.
- The temperature in the 1800s is much the same but the first graph keeps climbing.
- Between 1950 and 1980 the temperature didn't increase but the $CO_2$ did.
- From 1940 until 1975 the temperature stays about the same but the carbon dioxide emission shows a sharp rise.
- In 1940 the temperature is a lot higher than in 1920 and they have similar carbon dioxide emissions.

**Partial Credit:**

Mentions a correct period, without any explanation. For example:

- 1930–1933.
- before 1910.

Mentions only one particular year (not a period of time), with an acceptable explanation. For example:

- In 1980 the emissions were down but the temperature still rose.

Gives an example that doesn't support André's conclusion but makes a mistake in mentioning the period. *[Note: There should be evidence of this mistake – e.g. an area clearly illustrating a correct answer is marked on the graph and then a mistake made in transferring this information to the text.]* For example:

- Between 1950 and 1960 the temperature decreased and the carbon dioxide emission increased.

Refers to differences between the two curves, without mentioning a specific period. For example:

- At some places the temperature rises even if the emission decreases.
- Earlier there was little emission but nevertheless high temperature.
- When there is a steady increase in graph 1, there isn't an increase in graph 2, it stays constant. *[Note: It stays constant "overall".]*
- Because at the start the temperature is still high where the carbon dioxide was very low.

Refers to an irregularity in one of the graphs. For example:

- It is about 1910 when the temperature had dropped and went on for a certain period of time.
- In the second graph there is a decrease in temperature of the Earth's atmosphere just before 1910.

Indicates difference in the graphs, but explanation is poor. For example:

- In the 1940s the heat was very high but the carbon dioxide very low. *[Note: The explanation is very poor, but the difference that is indicated is clear.]*

### *Comment*

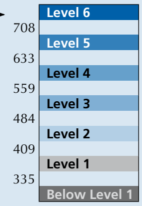
*Another example from GREENHOUSE centres on the competency* using scientific evidence *and asks students to identify a portion of a graph that does not provide evidence supporting a conclusion. This question requires the student to look for specific differences that vary from positively correlated general trends in these two graphical datasets. Students must locate a portion where curves are not both ascending or descending and provide this finding as part of a justification for a conclusion. As a consequence it involves a greater amount of insight and analytical skill than is required for Question 3. Rather than a generalisation about the relation between the graphs, the student is asked to accompany the nominated period of difference with an explanation of that difference in order to gain full credit.*

*The ability to effectively compare the detail of two datasets and give a critique of a given conclusion locates the full credit question at Level 5 of the* scientific literacy *scale. If the student understands what the question requires of them and correctly identifies a difference in the two graphs, but is unable to explain this difference, the student gains partial credit for the question and is identified at Level 4 of the* scientific literacy *scale.*

*This environmental issue is* global *which defines the setting. The skill required by students is to interpret data graphically presented so the question belongs in the "Scientific explanations" category.*

## GREENHOUSE – *QUESTION 5*

***Question type:*** *Open-constructed response*
***Competency:*** *Explaining phenomena scientifically*
***Knowledge category:*** *"Earth and space systems" (knowledge of science)*
***Application area:*** *"Environment"*
***Setting:*** *Global*
***Difficulty:*** *709*
***Percentage of correct answers (OECD countries):*** *18.9%*




André persists in his conclusion that the average temperature rise of the Earth's atmosphere is caused by the increase in the carbon dioxide emission. But Jeanne thinks that his conclusion is premature. She says: "Before accepting this conclusion you must be sure that other factors that could influence the greenhouse effect are constant".
Name one of the factors that Jeanne means.

.................................................................................................................................

.................................................................................................................................

### *Scoring*

**Full Credit:**

Gives a factor referring to the energy/radiation coming from the Sun. For example:

- The sun heating and maybe the earth changing position.
- Energy reflected back from Earth. *[Assuming that by "Earth" the student means "the ground".]*

Gives a factor referring to a natural component or a potential pollutant. For example:

- Water vapour in the air.
- Clouds.
- The things such as volcanic eruptions.
- Atmospheric pollution (gas, fuel).
- The amount of exhaust gas.
- CFC's.
- The number of cars.
- Ozone (as a component of air). *[Note: for references to depletion, use Code 03.]*

### *Comment*

*Question 5 of GREENHOUSE is an example of Level 6 and of the competency* explaining phenomena scientifically. *In this question, students must analyse a conclusion to account for other factors that could influence the greenhouse effect. This question combines aspects of the two competencies* identifying scientific issues and explaining phenomena scientifically. *The student needs to understand the necessity of controlling factors outside the change and measured variables and to recognise those variables. The student must possess sufficient knowledge of "Earth systems" to be able to identify at least one of the factors that should be controlled. The latter criterion is considered the critical scientific skill involved so this question is categorised as explaining phenomena scientifically. The effects of this environmental issue are* global, *which defines the setting.*

*As a first step in gaining credit for this question the student must be able to identify the change and measured variables and have sufficient understanding of methods of investigation to recognise the influence of other factors. However, the student also needs to recognise the scenario in context and identify its major components. This involves a number of abstract concepts and their relationships in determining what "other" factors might affect the relationship between the Earth's temperature and the amount of carbon dioxide emissions into the atmosphere. This locates the question near the boundary between Level 5 and 6 in the* explaining phenomena scientifically *category.*

■ Figure I.3.15 ■

**CLOTHES**

*Read the text and answer the questions that follow.*

**CLOTHES TEXT**

A team of British scientists is developing "intelligent" clothes that will give disabled children the power of "speech". Children wearing waistcoats made of a unique electrotextile, linked to a speech synthesiser, will be able to make themselves understood simply by tapping on the touch-sensitive material.

The material is made up of normal cloth and an ingenious mesh of carbon-impregnated fibres that can conduct electricity. When pressure is applied to the fabric, the pattern of signals that passes through the conducting fibres is altered and a computer chip can work out where the cloth has been touched. It then can trigger whatever electronic device is attached to it, which could be no bigger than two boxes of matches.

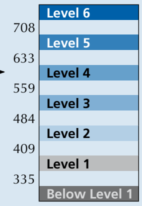
"The smart bit is in how we weave the fabric and how we send signals through it – and we can weave it into existing fabric designs so you cannot see it's in there," says one of the scientists.

Without being damaged, the material can be washed, wrapped around objects or scrunched up. The scientist also claims it can be mass-produced cheaply.

Source: Steve Farrer, "Interactive fabric promises a material gift of the garb", *The Australian*, 10 August 1998.

**CLOTHES** – *QUESTION 1*

***Question type***: *Complex multiple choice*
***Competency:*** *Identifying scientific issues*
***Knowledge category***: *"Scientific enquiry" (knowledge about science)*
***Application area:*** *"Frontiers of science and technology"*
***Setting:*** *Social*
***Difficulty:*** *567*
***Percentage of correct answers (OECD countries):*** *47.9%*




Can these claims made in the article be tested through scientific investigation in the laboratory?
Circle either "Yes" or "No" for each.

| The material can be | Can the claim be tested through scientific investigation in the laboratory? |
|---|---|
| washed without being damaged. | Yes / No |
| wrapped around objects without being damaged. | Yes / No |
| scrunched up without being damaged. | Yes / No |
| mass-produced cheaply. | Yes / No |

***Scoring***

**Full Credit:** Yes, Yes, Yes, No, in that order.

***Comment***

*The question requires the student to identify the change and measured variables associated with testing a claim about the clothing. It also involves an assessment of whether there are techniques to quantify the measured variable and whether other variables can be controlled. This process then needs to be accurately applied for all four claims. The issue of "intelligent" clothes is in the category "Frontiers of science and technology" and is a community issue addressing a need for disabled children so the setting is social. The scientific skills applied are concerned with the nature of investigation which places the question in the "Scientific enquiry" category.*

*The need to identify change and measured variables, together with an appreciation of what would be involved in carrying out measurement and controlling variables, locates the question at Level 4.*

■ Figure I.3.16 ■

**MARY MONTAGU**

*Read the following newspaper article and answer the questions that follow.*

**THE HISTORY OF VACCINATION**

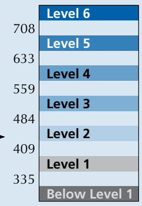
Mary Montagu was a beautiful woman. She survived an attack of smallpox in 1715 but she was left covered with scars. While living in Turkey in 1717, she observed a method called inoculation that was commonly used there. This treatment involved scratching a weak type of smallpox virus into the skin of healthy young people who then became sick, but in most cases only with a mild form of the disease.

Mary Montagu was so convinced of the safety of these inoculations that she allowed her son and daughter to be inoculated.

In 1796, Edward Jenner used inoculations of a related disease, cowpox, to produce antibodies against smallpox. Compared with the inoculation of smallpox, this treatment had less side effects and the treated person could not infect others. The treatment became known as vaccination.

**MARY MONTAGU** – *QUESTION 2*

***Question type:*** *Multiple choice*
***Competency:*** *Explaining phenomena scientifically*
***Knowledge category:*** *"Living systems" (knowledge of science)*
***Application area:*** *"Health"*
***Setting:*** *Social*
***Difficulty:*** *436*
***Percentage of correct answers (OECD countries):*** *74.9%*




What kinds of diseases can people be vaccinated against?

A. Inherited diseases like haemophilia.

B. Diseases that are caused by viruses, like polio.

C. Diseases from the malfunctioning of the body, like diabetes.

D. Any sort of disease that has no cure.

***Scoring***

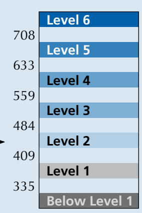
**Full Credit:** B. Diseases that are caused by viruses, like polio.

***Comment***

*To gain credit the student must recall a specific piece of knowledge that vaccination helps prevent diseases, the cause for which is external to normal body components. This fact is then applied in the selection of the correct explanation and the rejection of other explanations. The term "virus" appears in the stimulus text and provides a hint for students. This lowered the difficulty of the question. Recalling an appropriate, tangible scientific fact and its application in a relatively simple context locates the question at Level 2.*

**MARY MONTAGU** – *QUESTION 3*

***Question type:*** *Multiple choice*
***Competency:*** *Explaining phenomena scientifically*
***Knowledge category:*** *"Living systems" (knowledge of science)*
***Application area:*** *"Health"*
***Setting:*** *Social*
***Difficulty:*** *431*
***Percentage of correct answers (OECD countries):*** *75.1%*



If animals or humans become sick with an infectious bacterial disease and then recover, the type of bacteria that caused the disease does not usually make them sick again.

What is the reason for this?

A. The body has killed all bacteria that may cause the same kind of disease.

B. The body has made antibodies that kill this type of bacteria before they multiply.

C. The red blood cells kill all bacteria that may cause the same kind of disease.

D. The red blood cells capture and get rid of this type of bacteria from the body.

### *Scoring*

**Full Credit:** B. The body has made antibodies that kill this type of bacteria before they multiply.

### *Comment*

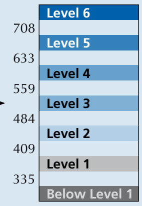
*To correctly answer this question the student must recall that the body produces antibodies that attack foreign bacteria, the cause of bacterial disease. Its application involves the further knowledge that these antibodies provide resistance to subsequent infections of the same bacteria. The issue is community control of disease, so the setting is social.*

*In selecting the appropriate explanation the student is recalling a tangible scientific fact and applying it in a relatively simple context. Consequently, the question is located at Level 2.*

---

## MARY MONTAGU – *QUESTION 4*

***Question type:*** *Open-constructed response*
***Competency:*** *Explaining phenomena scientifically*
***Knowledge category:*** *"Living systems" (knowledge of science)*
***Application area:*** *"Health"*
***Setting:*** *Social*
***Difficulty:*** *507*
***Percentage of correct answers (OECD countries):*** *61.7%*




Give one reason why it is recommended that young children and old people, in particular, should be vaccinated against influenza (flu).

............................................................................................................................................

............................................................................................................................................

............................................................................................................................................

### *Scoring*

**Full Credit:** Responses referring to young and/or old people having weaker immune systems than other people, or similar. For example:

These people have less resistance to getting sick.
The young and old can't fight off disease as easily as others.
They are more likely to catch the flu.
If they get the flu the effects are worse in these people.
Because organisms of young children and older people are weaker.
Old people get sick more easily.

### *Comment*

*This question requires the student to identify why young children and old people are more at risk of the effects of influenza than others in the population. Directly, or by inference, the reason is attributed to young children and old people having weaker immune systems. The issue is community control of disease, so the setting is* social.

*A correct explanation involves applying several pieces of knowledge that are well established in the community. The question stem also provides a cue to the groups having different resistance to disease. This puts the question at Level 3.*

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■ Figure I.3.17 ■

**GENETICALLY MODIFIED CROPS**

**GM CORN SHOULD BE BANNED**

Wildlife conservation groups are demanding that a new genetically modified (GM) corn be banned.

This GM corn is designed to be unaffected by a powerful new herbicide that kills conventional corn plants. This new herbicide will kill most of the weeds that grow in cornfields.

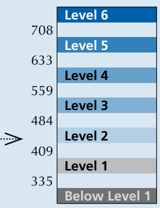
The conservationists say that because these weeds are feed for small animals, especially insects, the use of the new herbicide with the GM corn will be bad for the environment. Supporters of the use of the GM corn say that a scientific study has shown that this will not happen.

Here are details of the scientific study mentioned in the above article:

- Corn was planted in 200 fields across the country.
- Each field was divided into two. The genetically modified (GM) corn treated with the powerful new herbicide was grown in one half, and the conventional corn treated with a conventional herbicide was grown in the other half.
- The number of insects found in the GM corn, treated with the new herbicide, was about the same as the number of insects in the conventional corn, treated with the conventional herbicide.

## GENETICALLY MODIFIED CROPS – *QUESTION 3*

***Question type:*** *Multiple choice*
***Competency:*** *Identifying scientific issues*
***Knowledge category:*** *"Scientific enquiry" (knowledge about science)*
***Application area:*** *"Frontiers of science and technology"*
***Setting:*** *Social*
***Difficulty:*** *421*
***Percentage of correct answers (OECD countries):*** *73.6%*




Corn was planted in 200 fields across the country. Why did the scientists use more than one site?

A. So that many farmers could try the new GM corn.
B. To see how much GM corn they could grow.
C. To cover as much land as possible with the GM crop.
D. To include various growth conditions for corn.

### *Scoring*

**Full Credit:** D. To include various growth conditions for corn.

### *Comment*

*Towards the bottom of the scale, typical questions for Level 2 are exemplified by Question 3 from the unit GENETICALLY MODIFIED CROPS, which is for the competency* identifying scientific issues. *Question 3 asks a simple question about varying conditions in a scientific investigation and students are required to demonstrate knowledge about the design of science experiments.*

*To answer this question correctly in the absence of cues, the student needs to be aware that the effect of the treatment (different herbicides) on the outcome (insect numbers) could depend on environmental factors. Thus, by repeating the test in 200 locations the chance of a specific set of environmental factors giving rise to a spurious outcome can be accounted for. Since the question focuses on the methodology of the investigation it is categorised as "Scientific enquiry". The application area of genetic modification places this at the "Frontiers of science and technology" and given its restriction to one country it can be said to have a social setting.*

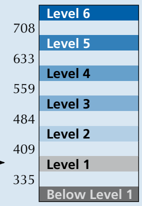
*In the absence of cues this question has the characteristics of Level 4,* i.e. *the student shows an awareness of the need to account for varying environmental factors and is able to recognise an appropriate way of dealing with that issue. However, the question actually performed at Level 2. This can be accounted for by the cues given in the three distractors. Students likely are able to easily eliminate these as options thus leaving the correct explanation as the answer. The effect is to reduce the difficulty of the question.*

■ Figure I.3.18 ■

**PHYSICAL EXERCISE**

*Regular but moderate physical exercise is good for our health.*

**PHYSICAL EXERCISE** – *QUESTION 3*




***Question type:*** *Complex multiple choice*
***Competency:*** *Explaining phenomena scientifically*
***Knowledge category:*** *"Living systems" (knowledge of science)*
***Application area:*** *"Health"*
***Setting:*** *Personal*
***Difficulty:*** *386*
***Percentage of correct answers (OECD countries):*** *82.4%*

What happens when muscles are exercised? Circle "Yes" or "No" for each statement.

| Does this happen when muscles are exercised? | Yes or No? |
|---|---|
| Muscles get an increased flow of blood. | Yes / No |
| Fats are formed in the muscles. | Yes / No |

### *Scoring*

**Full Credit:** Both correct: Yes, No, in that order.

### *Comment*

*For this question, to gain credit a student has to correctly recall knowledge about the operation of muscles and about the formation of fat in the body,* i.e. *students must have knowledge of the science fact that active muscles get an increased flow of blood and that fats are not formed when muscles are exercised. This enables the student to accept the first explanation of this complex multiple-choice question and reject the second explanation.*

*The two simple factual explanations contained in the question are not related to each other. Each is accepted or rejected as an effect of the exercise of muscles and the knowledge has widespread currency. Consequently, the question is located at Level 1. PHYSICAL EXERCISE, CLOTHES and GRAND CANYON are at Level 1 (below the cut-point), at the very bottom of the scale for the competency* explaining phenomena scientifically.

## STUDENT PERFORMANCE IN SCIENCE

When science was the major subject in 2006, six proficiency levels were defined on the science scale. These same proficiency levels are used for reporting science results in PISA 2009. The process used to produce proficiency levels in science is similar to that used to produce proficiency levels in reading and mathematics, as described in Volume I, Chapter 2.

Figure I.3.19 presents a description of the scientific knowledge and skills which students possess at the various proficiency levels, with Level 6 being the highest level of proficiency.

■ Figure I.3.19 ■

**Summary descriptions for the six levels of proficiency in science**

| Level | Lower score limit | What students can typically do |
|---|---|---|
| 6 | 708 | At Level 6, students can consistently identify, explain and apply scientific knowledge and *knowledge about science* in a variety of complex life situations. They can link different information sources and explanations and use evidence from those sources to justify decisions. They clearly and consistently demonstrate advanced scientific thinking and reasoning, and they demonstrate willingness to use their scientific understanding in support of solutions to unfamiliar scientific and technological situations. Students at this level can use scientific knowledge and develop arguments in support of recommendations and decisions that centre on *personal, social* or *global* situations. |
| 5 | 633 | At Level 5, students can identify the scientific components of many complex life situations, apply both scientific concepts and *knowledge about science* to these situations, and can compare, select and evaluate appropriate scientific evidence for responding to life situations. Students at this level can use well-developed inquiry abilities, link knowledge appropriately and bring critical insights to situations. They can construct explanations based on evidence and arguments based on their critical analysis. |
| 4 | 559 | At Level 4, students can work effectively with situations and issues that may involve explicit phenomena requiring them to make inferences about the role of science or technology. They can select and integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations. Students at this level can reflect on their actions and they can communicate decisions using scientific knowledge and evidence. |
| 3 | 484 | At Level 3, students can identify clearly described scientific issues in a range of contexts. They can select facts and knowledge to explain phenomena and apply simple models or inquiry strategies. Students at this level can interpret and use scientific concepts from different disciplines and can apply them directly. They can develop short statements using facts and make decisions based on scientific knowledge. |
| 2 | 409 | At Level 2, students have adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving. |
| 1 | 335 | At Level 1, students have such a limited scientific knowledge that it can only be applied to a few, familiar situations. They can present scientific explanations that are obvious and follow explicitly from given evidence. |

***Proficiency at Level 6 (scores higher than 708 points)***

Students proficient at Level 6 on the science scale can consistently identify, explain and apply scientific knowledge and *knowledge about science* in a variety of complex life situations. They can link different information sources and explanations and use evidence from those sources to justify decisions. They clearly and consistently demonstrate advanced scientific thinking and reasoning, and they use their scientific understanding to solve unfamiliar scientific and technological situations. Students at this level can use scientific knowledge and develop arguments in support of recommendations and decisions that centre on personal, social, or global situations.

Across OECD countries, an average of 1.1% of students perform at Level 6. Between 2% and 5% of the students are at this level in New Zealand (3.6%), Finland (3.3%), Australia (3.1%) and Japan (2.6%) as well as in the partner countries and economies Singapore (4.6%), Shanghai-China (3.9%) and Hong Kong-China (2.0%). In Mexico, Chile and Turkey, 0% of students reach this level, and the situation is similar in half of the partner countries, namely Indonesia, Azerbaijan, Kyrgyzstan, Montenegro, Panama, Albania, Colombia, Tunisia, Jordan, Romania, Brazil, Kazakhstan, Peru, Serbia, Thailand and Argentina.

***Proficiency at Level 5 (scores higher than 633 but lower than or equal to 708 points)***

Students proficient at Level 5 can identify the scientific components of many complex life situations, apply both scientific concepts and *knowledge about science* to these situations, and can compare, select and evaluate appropriate scientific evidence for responding to life situations. Students at this level can use well-developed inquiry abilities, link knowledge appropriately and bring critical insights to situations. They can construct explanations based on evidence and arguments that emerge from their critical analysis.

Across OECD countries, 8.5% of students are proficient at Levels 5 or 6 (Figure I.3.21 and Table I.3.4). More than 15% of students are in either of these levels in Finland (18.7%), New Zealand (17.6%) and Japan (16.9 %), as well as in the partner countries and economies Shanghai-China (24.3%), Singapore (19.9%) and Hong Kong-China (16.2%). In three partner countries, Indonesia, Azerbaijan and Kyrgyzstan, 0% of students reach at least Level 5. Those countries with 0.5% or less of students at these levels are Mexico (0.2%) and the partner countries Albania (0.1%), Colombia (0.1%), Tunisia (0.2%), Peru (0.2%), Panama (0.2%), Montenegro (0.2%), Kazakhstan (0.3%), Romania (0.4%) and Jordan (0.5%).

***Proficiency at Level 4 (scores higher than 559 but lower than or equal to 633 points)***

Students proficient at Level 4 work effectively with situations and issues that may involve explicit phenomena requiring them to make inferences about the role of science or technology. They can select and integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations. Students at this level can reflect on their actions and can communicate decisions using scientific knowledge and evidence.

Across OECD countries, an average of 29.1% of students is proficient at Level 4 or higher (Level 4, 5 or 6) (Figure I.3.21 and Table I.3.4). Half of all students in Finland perform at Level 4, 5 or 6, and more than 60% do so in the partner economy Shanghai-China. Between 35% and 49% of students perform at one of these levels in Japan (46.4%), New Zealand (42.8%), Korea (42.0%), Australia (39.0%), Canada (38.3%), the Netherlands (38.1%), Germany (37.8%) and Estonia (36.1%), as well as in the partner countries and economies Hong Kong-China (48.9%), Singapore (45.6%) and Liechtenstein (35.1%). In contrast, less than 5% of students reach Level 4, 5 or 6 in Mexico (3.3%) and in the partner countries Indonesia (0.5%), Kyrgyzstan (0.8%), Azerbaijan (0.8%), Peru (2.0%), Albania (2.1%), Tunisia (2.3%), Panama (2.4%), Colombia (2.6%), Montenegro (3.4%), Kazakhstan (3.9%), Brazil (4.4%), Jordan (4.6%) and Romania (4.8%).

***Proficiency at Level 3 (scores higher than 484 but lower than or equal to 559 points)***

Students proficient at Level 3 can identify clearly described scientific issues in a range of contexts. They can select facts and tap knowledge to explain phenomena and apply simple models or inquiry strategies. Students at this level can interpret and use scientific concepts from different disciplines and can apply them directly. They can develop short statements using facts and make decisions based on scientific knowledge.

Across OECD countries, 57.7% of students are proficient to Level 3 or higher (Level 3, 4, 5 or 6) on the science scale (Figure I.3.21 and Table I.3.4). In the OECD countries Finland (78.7%) and Korea (75.2%), as well as in the partner economies Shanghai-China (86.3%) and Hong Kong-China (78.3%), over three-quarters of 15-year-olds are proficient to Level 3 or higher, and at least two-thirds of students in the OECD countries Japan (73.1%), Estonia (70.4%), Canada (69.6%), New Zealand (68.6%) and Australia (67.5%), and in the partner countries and economies Singapore (71.0%) and Chinese Taipei (67.8%) perform at least at this level.

***Proficiency at Level 2 (scores higher than 409 but lower than or equal to 484 points)***

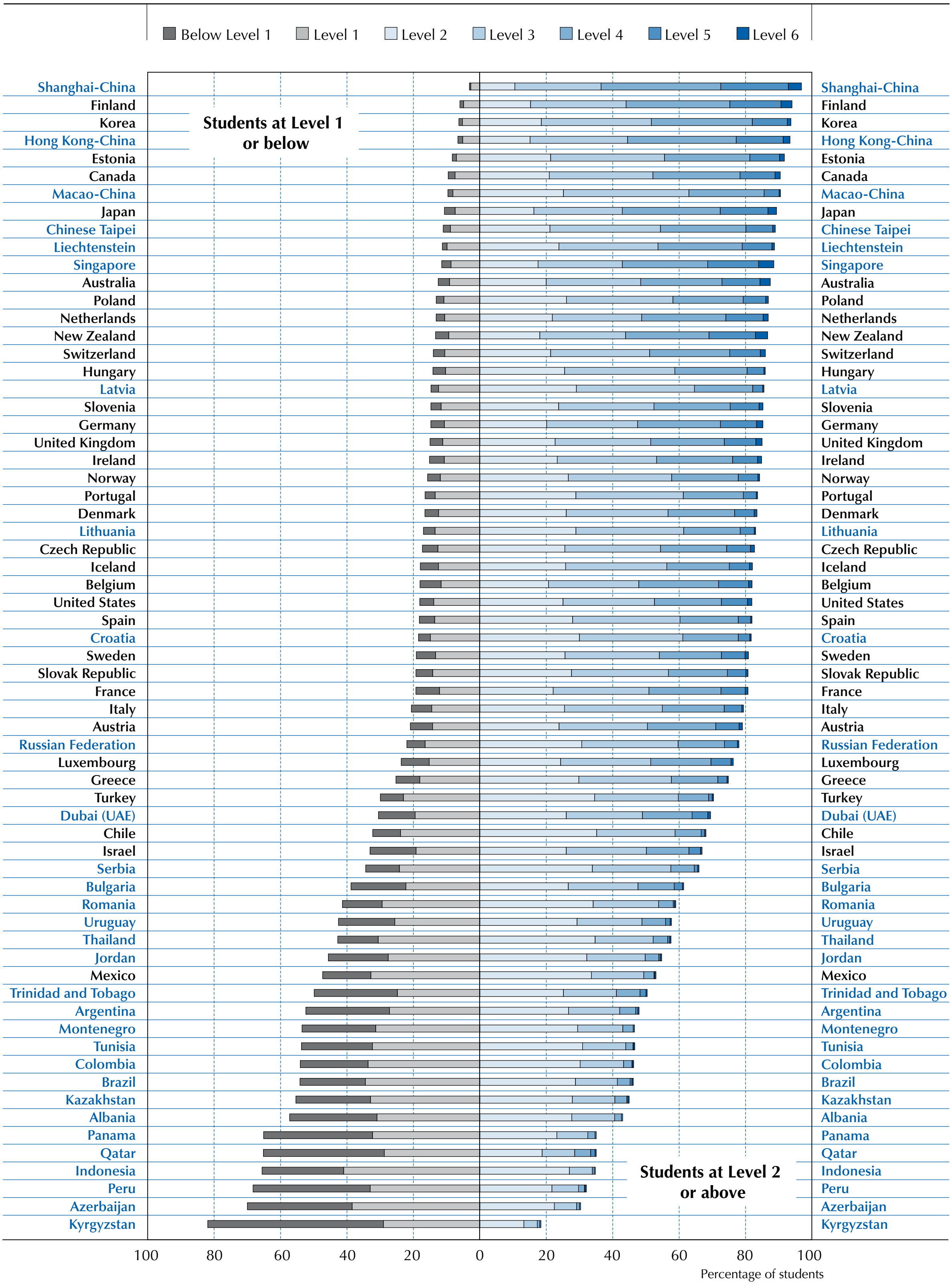
Students proficient at Level 2 have adequate scientific knowledge to provide possible explanations in familiar contexts or to draw conclusions based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving. Level 2 has been established as the baseline level, defining the level of achievement on the PISA scale at which students begin to demonstrate the science competencies that will enable them to participate actively in life situations related to science and technology.

Across OECD countries, an average of 82% of students are proficient at Level 2 or higher. In Finland (94.0%), Korea (93.7%), Estonia (91.7%) and Canada (90.4%), as well as in the partner economies Shanghai-China (96.8%), Hong Kong-China (93.4%) and Macao-China (90.4%), more than 90% of students perform at or above this threshold. In every country except the three partner countries Kyrgyzstan (18.0%), Azerbaijan (30.0%) and Peru (31.7%), at least two-thirds of students are at Level 2 or above (Figure I.3.21 and Table I.3.4).

■ Figure I.3.20 ■

**How proficient are students in science?**

*Percentage of students at the different levels of science proficiency*




*Countries are ranked in descending order of the percentage of students at Levels 2, 3, 4, 5 and 6.*
Source: OECD, *PISA 2009 Database*, Table I.3.4.
StatLink http://dx.doi.org/10.1787/888932343152

***Proficiency at Level 1 (scores higher than 335 but lower than or equal to 409 points) or below***

Students proficient at Level 1 have such limited scientific knowledge that it can only be applied to a few, familiar situations. They can present scientific explanations that are obvious and follow explicitly from given evidence.

Students performing below 335 score points – that is, below Level 1 – usually do not succeed at the most basic levels of science that PISA measures. Such students will have serious difficulties in using science to benefit from further education and learning opportunities and participate in life situations related to science and technology.

Across OECD countries, 18% of students perform below Level 2, 13% of students perform at Level 1 and 5% perform below Level 1. In Finland (6.0%), Korea (6.3%), Estonia (8.3%) and Canada (9.6%), as well as the partner economies Shanghai-China (3.2%), Hong Kong-China (6.6%) and Macao-China (9.6%), less than 10% of students perform at or below Level 1. In all other OECD countries, the percentage of students performing at or below Level 1 ranges from 10.7% in Japan to 47.4% in Mexico. More than three-quarters of students perform above Level 2 in the partner country Kyrgyzstan (82.0%) (Figure I.3.21 and Table I.3.4).

## Mean country performance in science

Countries' performance in science can be summarised by a mean score. Science was the focus of the PISA 2006 survey. The mean in science for OECD countries was set at 498 in PISA 2006 and at 501 in PISA 2009.

When interpreting mean performance, only those differences between countries that are statistically significant should be taken into account. Figure I.3.21 shows each country's mean score, and allows readers to see for which pairs of countries the differences between the means shown are statistically significant. For each country shown on the left in the middle column, the list of countries in the right hand column shows countries whose mean scores are not sufficiently different to be distinguished with confidence. For all other cases, one country has higher performance than another if it is above it in the list in the middle column, and lower performance if it is below. For example: Shanghai-China, ranks first on the PISA science scale, but Finland, which appears second on the list, cannot be distinguished with confidence from Hong Kong-China, which appears third.

Three countries and economies outperform all other countries and economies in science in PISA 2009 with more than half a standard deviation above the average: the OECD country Finland, with 554 score points, and the partner economies Shanghai-China and Hong Kong-China, with 575 and 549 score points, respectively. Japan and Korea and the partner country Singapore have mean scores of 539, 538 and 542, respectively, which are around half a proficiency level or above the average of 501 score points in PISA 2009. Other countries with mean performances above the average include New Zealand, Canada, Estonia, Australia, the Netherlands, Germany, Switzerland, the United Kingdom, Slovenia, Poland, Ireland and Belgium, and the partner countries and economies Chinese Taipei, Liechtenstein and Macao-China. Countries that performed around the average include Hungary, the United States, the Czech Republic, Norway, Denmark and France.

The gap in performance between the highest and the lowest performing OECD countries is 138 score points. That is, while the average score of the highest performing country, Finland, is 554, or more than half a standard deviation above the average, Mexico's average score of 416 score points is almost one standard deviation below the average. But the gap among the partner countries and economies is even larger, with 245 score points of difference between Shanghai-China (575) and Kyrgyzstan (330).

Because the figures are derived from samples, it is not possible to determine a precise rank of a country's performance among the participating countries. It is possible, however, to determine with confidence a range of ranks in which the country's performance level lies (Figure I.3.22).

The performance difference between students within countries and economies is shown in Table I.3.6. The distribution of student performance in science within countries and economies is even larger than in mathematics, ranging from 227 to 358 score points. Among OECD countries, some of the lower performing countries, such as Mexico, Turkey and Chile, show the narrowest distributions between the 5th and 95th percentile in the OECD, with this difference equivalent to 254, 265 and 268 score points, respectively. However, Korea shows a difference of 266 score points, but is among the 3 highest-performing OECD countries. In the same way, Shanghai-China, with the best score in science for PISA 2009, has a narrow distribution, with only 270 score points.

■ Figure I.3.21 ■

## Comparing countries' performance in science

- Statistically significantly **above** the OECD average
- Not statistically significantly different from the OECD average
- Statistically significantly **below** the OECD average

| Mean | Comparison country | Countries whose mean score is NOT statistically significantly different from that comparison country |
|---|---|---|
| 575 | Shanghai-China | |
| 554 | Finland | Hong Kong-China |
| 549 | Hong Kong-China | Finland |
| 542 | Singapore | Japan, Korea |
| 539 | Japan | Singapore, Korea, New Zealand |
| 538 | Korea | Singapore, Japan, New Zealand |
| 532 | New Zealand | Japan, Korea, Canada, Estonia, Australia, Netherlands |
| 529 | Canada | New Zealand, Estonia, Australia, Netherlands |
| 528 | Estonia | New Zealand, Canada, Australia, Netherlands, Germany, Liechtenstein |
| 527 | Australia | New Zealand, Canada, Estonia, Netherlands, Chinese Taipei, Germany, Liechtenstein |
| 522 | Netherlands | New Zealand, Canada, Estonia, Australia, Chinese Taipei, Germany, Liechtenstein, Switzerland, United Kingdom, Slovenia |
| 520 | Chinese Taipei | Australia, Netherlands, Germany, Liechtenstein, Switzerland, United Kingdom |
| 520 | Germany | Estonia, Australia, Netherlands, Chinese Taipei, Liechtenstein, Switzerland, United Kingdom |
| 520 | Liechtenstein | Estonia, Australia, Netherlands, Chinese Taipei, Germany, Switzerland, United Kingdom |
| 517 | Switzerland | Netherlands, Chinese Taipei, Germany, Liechtenstein, United Kingdom, Slovenia, Macao-China |
| 514 | United Kingdom | Netherlands, Chinese Taipei, Germany, Liechtenstein, Switzerland, Slovenia, Macao-China, Poland, Ireland |
| 512 | Slovenia | Netherlands, Switzerland, United Kingdom, Macao-China, Poland, Ireland, Belgium |
| 511 | Macao-China | Switzerland, United Kingdom, Slovenia, Poland, Ireland, Belgium |
| 508 | Poland | United Kingdom, Slovenia, Macao-China, Ireland, Belgium, Hungary, United States |
| 508 | Ireland | United Kingdom, Slovenia, Macao-China, Poland, Belgium, Hungary, United States, Czech Republic, Norway |
| 507 | Belgium | Slovenia, Macao-China, Poland, Ireland, Hungary, United States, Czech Republic, Norway, France |
| 503 | Hungary | Poland, Ireland, Belgium, United States, Czech Republic, Norway, Denmark, France, Sweden, Austria |
| 502 | United States | Poland, Ireland, Belgium, Hungary, Czech Republic, Norway, Denmark, France, Iceland, Sweden, Austria, Latvia, Portugal |
| 500 | Czech Republic | Ireland, Belgium, Hungary, United States, Norway, Denmark, France, Iceland, Sweden, Austria, Latvia, Portugal |
| 500 | Norway | Ireland, Belgium, Hungary, United States, Czech Republic, Denmark, France, Iceland, Sweden, Austria, Latvia, Portugal |
| 499 | Denmark | Hungary, United States, Czech Republic, Norway, France, Iceland, Sweden, Austria, Latvia, Portugal |
| 498 | France | Belgium, Hungary, United States, Czech Republic, Norway, Denmark, Iceland, Sweden, Austria, Latvia, Portugal, Lithuania, Slovak Republic |
| 496 | Iceland | United States, Czech Republic, Norway, Denmark, France, Sweden, Austria, Latvia, Portugal, Lithuania, Slovak Republic |
| 495 | Sweden | Hungary, United States, Czech Republic, Norway, Denmark, France, Iceland, Austria, Latvia, Portugal, Lithuania, Slovak Republic, Italy |
| 494 | Austria | Hungary, United States, Czech Republic, Norway, Denmark, France, Iceland, Sweden, Latvia, Portugal, Lithuania, Slovak Republic, Italy, Spain, Croatia |
| 494 | Latvia | United States, Czech Republic, Norway, Denmark, France, Iceland, Sweden, Austria, Portugal, Lithuania, Slovak Republic, Italy, Spain, Croatia |
| 493 | Portugal | United States, Czech Republic, Norway, Denmark, France, Iceland, Sweden, Austria, Latvia, Lithuania, Slovak Republic, Italy, Spain, Croatia |
| 491 | Lithuania | France, Iceland, Sweden, Austria, Latvia, Portugal, Slovak Republic, Italy, Spain, Croatia |
| 490 | Slovak Republic | France, Iceland, Sweden, Austria, Latvia, Portugal, Lithuania, Italy, Spain, Croatia |
| 489 | Italy | Sweden, Austria, Latvia, Portugal, Lithuania, Slovak Republic, Spain, Croatia |
| 488 | Spain | Austria, Latvia, Portugal, Lithuania, Slovak Republic, Italy, Croatia, Luxembourg |
| 486 | Croatia | Austria, Latvia, Portugal, Lithuania, Slovak Republic, Italy, Spain, Luxembourg, Russian Federation |
| 484 | Luxembourg | Spain, Croatia, Russian Federation |
| 478 | Russian Federation | Croatia, Luxembourg, Greece |
| 470 | Greece | Russian Federation, Dubai (UAE) |
| 466 | Dubai (UAE) | Greece |
| 455 | Israel | Turkey, Chile |
| 454 | Turkey | Israel, Chile |
| 447 | Chile | Israel, Turkey, Serbia, Bulgaria |
| 443 | Serbia | Chile, Bulgaria |
| 439 | Bulgaria | Chile, Serbia, Romania, Uruguay |
| 428 | Romania | Bulgaria, Uruguay, Thailand |
| 427 | Uruguay | Bulgaria, Romania, Thailand |
| 425 | Thailand | Romania, Uruguay |
| 416 | Mexico | Jordan |
| 415 | Jordan | Mexico, Trinidad and Tobago |
| 410 | Trinidad and Tobago | Jordan, Brazil |
| 405 | Brazil | Trinidad and Tobago, Colombia, Montenegro, Argentina, Tunisia, Kazakhstan |
| 402 | Colombia | Brazil, Montenegro, Argentina, Tunisia, Kazakhstan |
| 401 | Montenegro | Brazil, Colombia, Argentina, Tunisia, Kazakhstan |
| 401 | Argentina | Brazil, Colombia, Montenegro, Tunisia, Kazakhstan, Albania |
| 401 | Tunisia | Brazil, Colombia, Montenegro, Argentina, Kazakhstan |
| 400 | Kazakhstan | Brazil, Colombia, Montenegro, Argentina, Tunisia, Albania |
| 391 | Albania | Argentina, Kazakhstan, Indonesia |
| 383 | Indonesia | Albania, Qatar, Panama, Azerbaijan |
| 379 | Qatar | Indonesia, Panama |
| 376 | Panama | Indonesia, Qatar, Azerbaijan, Peru |
| 373 | Azerbaijan | Indonesia, Panama, Peru |
| 369 | Peru | Panama, Azerbaijan |
| 330 | Kyrgyzstan | |

Source: OECD, *PISA 2009 Database*.
StatLink http://dx.doi.org/10.1787/888932343152

■ Figure I.3.22 ■

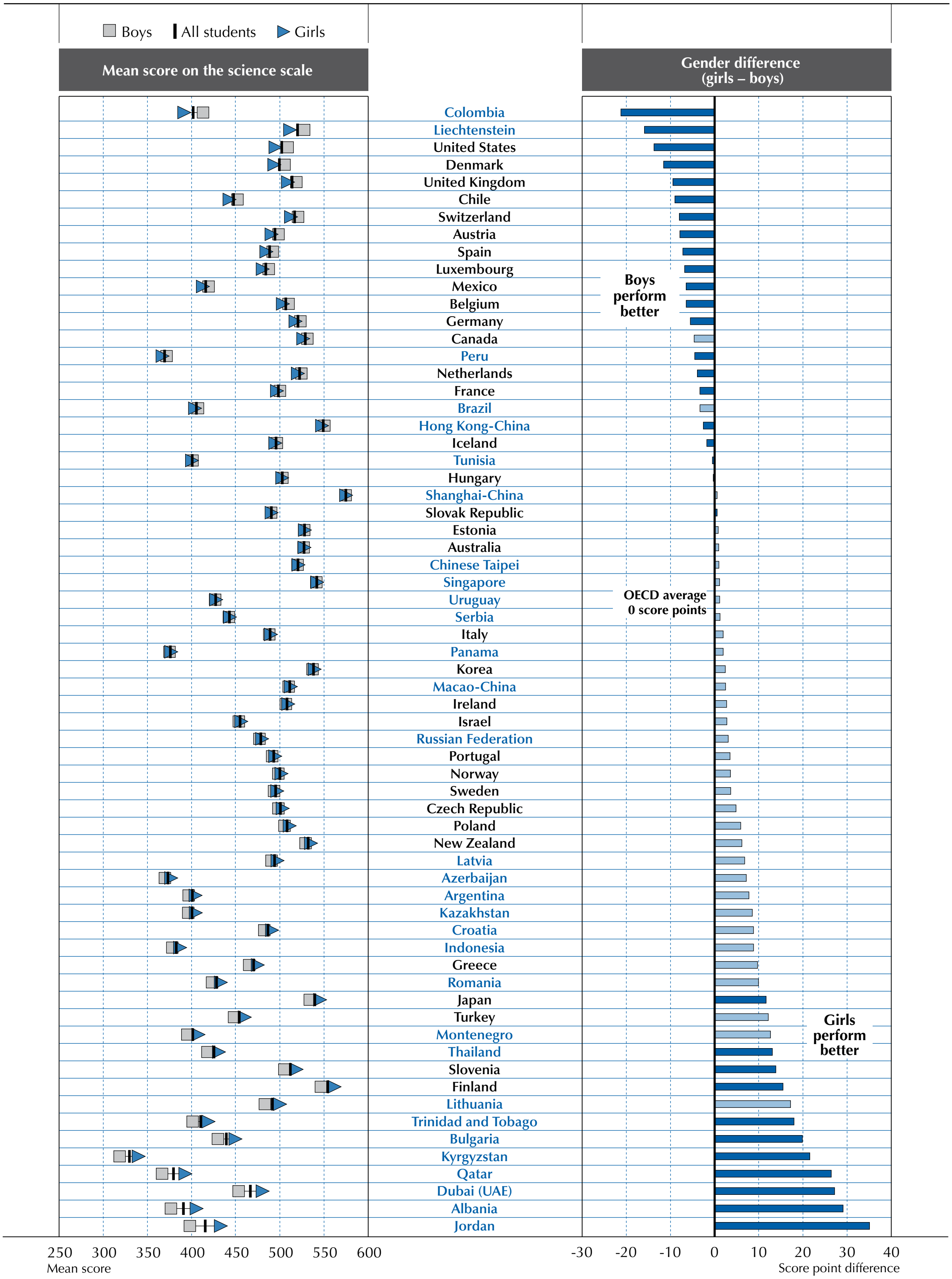
## Where countries rank in science performance

Statistically significantly **above** the OECD average
Not statistically significantly different from the OECD average
Statistically significantly **below** the OECD average

| | Science | | | | | |
|---|---|---|---|---|---|---|
| | | | Range of rank | | | |
| | | | OECD countries | | All countries/economies | |
| | Mean Score | S.E. | Upper rank | Lower rank | Upper rank | Lower rank |
| Shanghai-China | 575 | (2.3) | | | 1 | 1 |
| Finland | 554 | (2.3) | 1 | 1 | 2 | 3 |
| Hong Kong-China | 549 | (2.8) | | | 2 | 3 |
| Singapore | 542 | (1.4) | | | 4 | 6 |
| Japan | 539 | (3.4) | 2 | 3 | 4 | 6 |
| Korea | 538 | (3.4) | 2 | 4 | 4 | 7 |
| New Zealand | 532 | (2.6) | 3 | 6 | 6 | 9 |
| Canada | 529 | (1.6) | 4 | 7 | 7 | 10 |
| Estonia | 528 | (2.7) | 4 | 8 | 7 | 11 |
| Australia | 527 | (2.5) | 4 | 8 | 7 | 11 |
| Netherlands | 522 | (5.4) | 4 | 11 | 7 | 16 |
| Chinese Taipei | 520 | (2.6) | | | 11 | 15 |
| Germany | 520 | (2.8) | 7 | 10 | 10 | 15 |
| Liechtenstein | 520 | (3.4) | | | 10 | 16 |
| Switzerland | 517 | (2.8) | 8 | 12 | 12 | 17 |
| United Kingdom | 514 | (2.5) | 9 | 13 | 14 | 19 |
| Slovenia | 512 | (1.1) | 10 | 13 | 16 | 19 |
| Macao-China | 511 | (1.0) | | | 16 | 19 |
| Poland | 508 | (2.4) | 12 | 16 | 17 | 22 |
| Ireland | 508 | (3.3) | 11 | 17 | 16 | 23 |
| Belgium | 507 | (2.5) | 12 | 17 | 18 | 24 |
| Hungary | 503 | (3.1) | 13 | 21 | 19 | 27 |
| United States | 502 | (3.6) | 13 | 22 | 19 | 29 |
| Czech Republic | 500 | (3.0) | 15 | 23 | 21 | 29 |
| Norway | 500 | (2.6) | 16 | 23 | 21 | 29 |
| Denmark | 499 | (2.5) | 16 | 23 | 22 | 30 |
| France | 498 | (3.6) | 16 | 25 | 22 | 33 |
| Iceland | 496 | (1.4) | 20 | 25 | 26 | 32 |
| Sweden | 495 | (2.7) | 19 | 26 | 25 | 34 |
| Austria | 494 | (3.2) | 19 | 28 | 25 | 36 |
| Latvia | 494 | (3.1) | | | 25 | 35 |
| Portugal | 493 | (2.9) | 21 | 28 | 27 | 36 |
| Lithuania | 491 | (2.9) | | | 28 | 37 |
| Slovak Republic | 490 | (3.0) | 23 | 29 | 29 | 37 |
| Italy | 489 | (1.8) | 25 | 28 | 32 | 37 |
| Spain | 488 | (2.1) | 25 | 29 | 32 | 37 |
| Croatia | 486 | (2.8) | | | 33 | 39 |
| Luxembourg | 484 | (1.2) | 28 | 29 | 37 | 39 |
| Russian Federation | 478 | (3.3) | | | 38 | 40 |
| Greece | 470 | (4.0) | 30 | 30 | 39 | 41 |
| Dubai (UAE) | 466 | (1.2) | | | 40 | 41 |
| Israel | 455 | (3.1) | 31 | 32 | 42 | 43 |
| Turkey | 454 | (3.6) | 31 | 33 | 42 | 44 |
| Chile | 447 | (2.9) | 32 | 33 | 43 | 45 |
| Serbia | 443 | (2.4) | | | 44 | 46 |
| Bulgaria | 439 | (5.9) | | | 44 | 47 |
| Romania | 428 | (3.4) | | | 47 | 49 |
| Uruguay | 427 | (2.6) | | | 47 | 49 |
| Thailand | 425 | (3.0) | | | 47 | 49 |
| Mexico | 416 | (1.8) | 34 | 34 | 50 | 51 |
| Jordan | 415 | (3.5) | | | 50 | 52 |
| Trinidad and Tobago | 410 | (1.2) | | | 51 | 53 |
| Brazil | 405 | (2.4) | | | 52 | 56 |
| Colombia | 402 | (3.6) | | | 53 | 58 |
| Montenegro | 401 | (2.0) | | | 54 | 58 |
| Argentina | 401 | (4.6) | | | 53 | 59 |
| Tunisia | 401 | (2.7) | | | 53 | 58 |
| Kazakhstan | 400 | (3.1) | | | 53 | 58 |
| Albania | 391 | (3.9) | | | 58 | 60 |
| Indonesia | 383 | (3.8) | | | 59 | 62 |
| Qatar | 379 | (0.9) | | | 60 | 62 |
| Panama | 376 | (5.7) | | | 60 | 64 |
| Azerbaijan | 373 | (3.1) | | | 62 | 64 |
| Peru | 369 | (3.5) | | | 62 | 64 |
| Kyrgyzstan | 330 | (2.9) | | | 65 | 65 |

Source: OECD, *PISA 29 Database*.
StatLink http://dx.doi.org/10.1787/888932343152

■ Figure I.3.23 ■
## Gender differences in science performance




Note: Statistically significant gender differences are marked in a darker tone (see Annex A3).
*Countries are ranked in ascending order of the gender score point difference (girls – boys).*
Source: OECD, *PISA 2009 Database*, Table I.3.6.
StatLink http://dx.doi.org/10.1787/888932343152

## Gender differences in science

Across OECD countries, gender differences in science performance tend to be small, both in absolute terms and when compared with the large gender gap in reading performance and the more moderate gender differences in mathematics. In most countries, differences in the average score for boys and girls are not statistically significant. This shows that science is a subject where gender equality is closer to reality than in mathematics or reading. In 2006, when science was the main focus of assessment, gender differences were observed in two of the science processes being assessed: across OECD countries, girls scored higher in the area of *identifying scientific issues*, while boys outscored girls in *explaining phenomena scientifically*. The shorter assessment time in science in 2009, did not allow for a re-analysis of this finding.

The largest gender differences in favour of boys are observed in the United States and Denmark, with 14 and 12 score points, respectively, and in the partner countries Colombia and Liechtenstein, with 21 and 16 score points, respectively. In the United Kingdom, Chile, Switzerland, Spain, Luxembourg, Mexico and Canada, boys outperform girls in science with a difference that ranges from five to nine score points. On the other hand, girls outperform boys in science in Finland, Slovenia, Turkey and Greece, with a difference of 10 to 15 score points, and in Poland with a difference of 6 score points. In the partner countries Jordan, Albania, Dubai (UAE), Qatar, Kyrgyzstan, Bulgaria, Trinidad and Tobago, Lithuania, Thailand, Montenegro and Romania, which perform below the average, the advantage of girls ranges from 10 to 35 score points. This is also the case for the partner countries Indonesia, Kazakhstan, Argentina, Azerbaijan and Latvia, with a smaller difference that varies between six and nine score points (Table I.3.6).

### Box I.3.1 Top performers in reading, mathematics or science

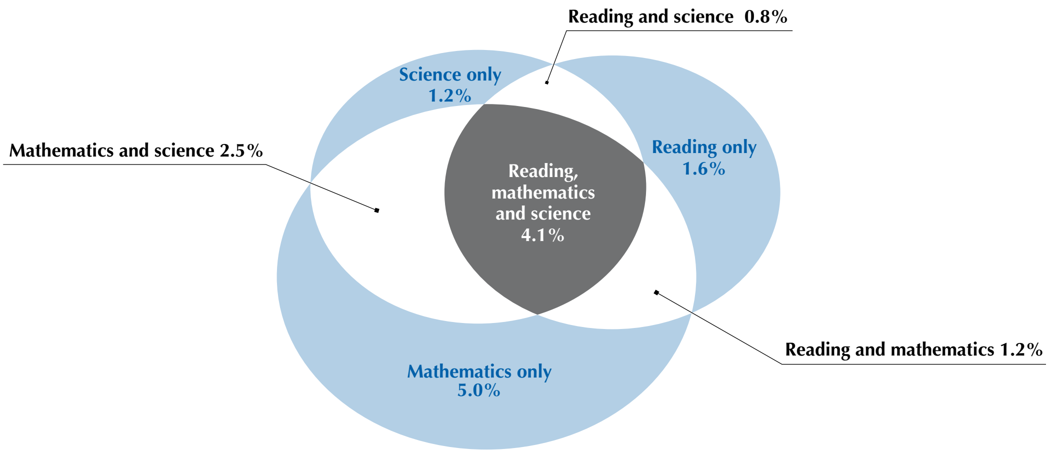
The rapidly growing demand for highly skilled workers has led to a global competition for talent. High-level skills are critical for creating new knowledge, technologies and innovation and, as such, are key to economic growth and social development. Looking at the top performing students in reading, mathematics and science allows countries to estimate their future talent pool. [See (OECD, 2009)]

"Top performers" in reading, mathematics or science refer to students who attain Level 5 or 6 in these subjects, *i.e.* perform higher than 626 score points in reading, 607 score points in mathematics, or 633 score points in science.

Figure I.3.a shows the proportion of top performers in the three subject areas across OECD countries. Parts in the diagram in blue represent the percentage of 15-year-old students who are top performers in just one of the three assessment subject areas, that is, in either reading, mathematics or science. The parts in grey show the percentage of students who are top performers in two of the subject areas, while the white part in the centre of the diagram shows the percentage of 15-year-old students who are top performers in all three assessment subject areas.

■ Figure I.3.a ■

**Overlapping of top performers in reading, mathematics and science on average in the OECD**



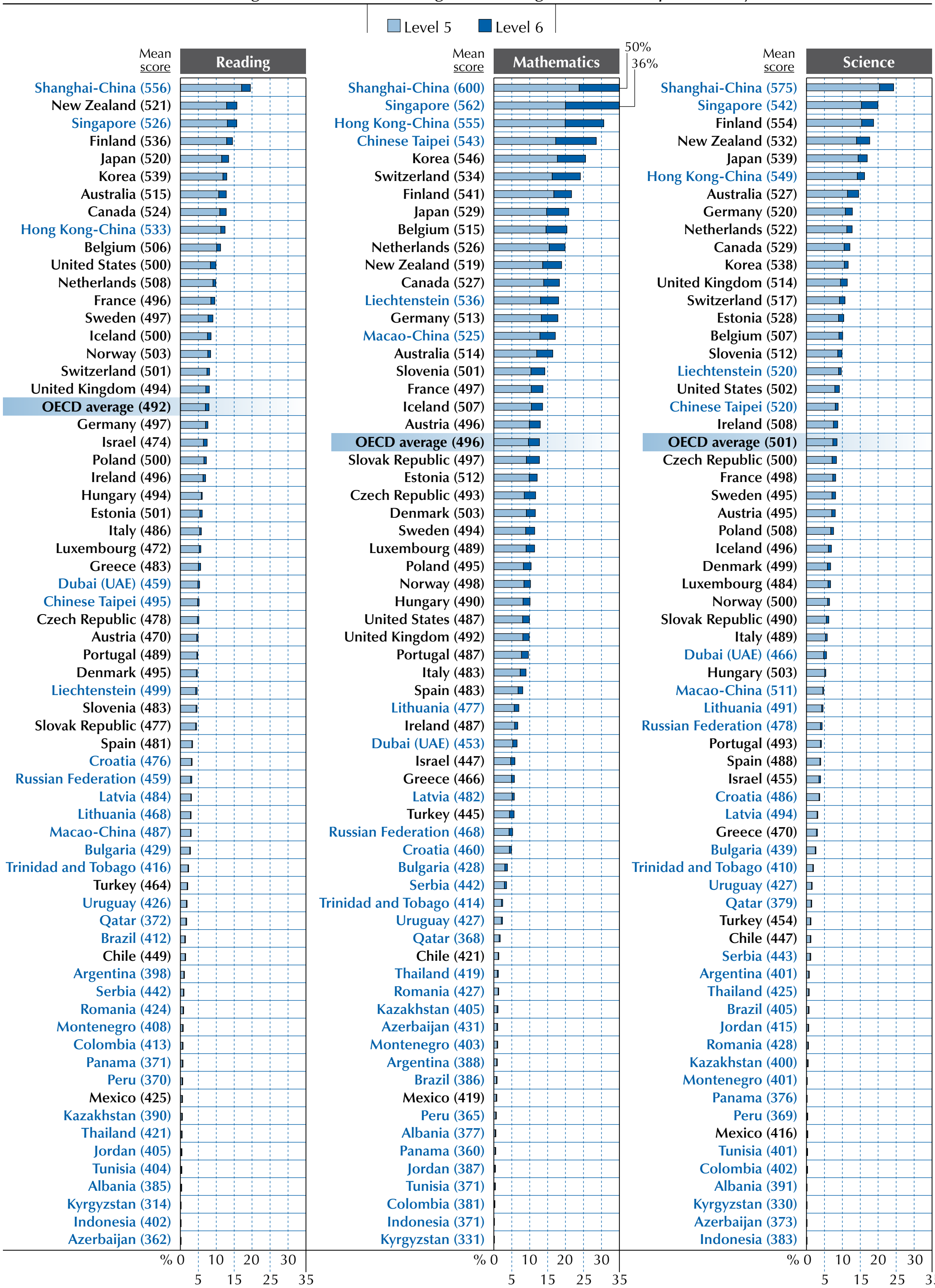

Note: Non-top performers in any of the three domains: 83.7%.
Source: OECD, *PISA 2009 Database*, Table I.3.7.
StatLink http://dx.doi.org/10.1787/888932343152

...

■ Figure I.3.b ■

**Top performers in reading, mathematics and science**

*Percentage of students reaching the two highest levels of proficiency*




*Countries are ranked in descending order of the percentage of top performers (Level 5 or 6).*

Source: OECD, *PISA 2009 Database*, Tables I.2.1, I.3.1 and I.3.4.

StatLink http://dx.doi.org/10.1787/888932343152

On average across OECD countries, 16.3% of students are top performers in at least one of the subject areas of science, mathematics or reading. However, only 4.1% of 15-year-old students are top performers in all three assessment subject areas. This shows that excellence is not simply strong performance in all areas, but rather that it can be found among a wide range of students in various subject areas.

About 1.2% of students are top performers in both reading and mathematics but not in science, less than 1% of students (0.8%) are top performers in both reading and science but not in mathematics, and 2.4% are top performers in both mathematics and science but not in reading. The percentage of students who are top performers in both mathematics and science is greater than the percentages who are top performers in reading and mathematics or in reading and science.

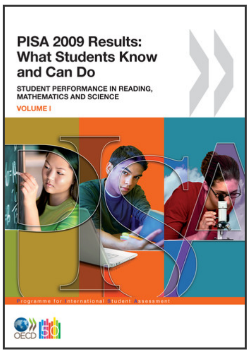
There is substantial variation among countries in the percentages of top performers in the three subjects (see Table I.3.7). Top performers comprise between 8% and 10% of 15-year-old students in New Zealand, Finland, Japan and Australia, and in the partner economy Hong Kong-China, and even more in the partner countries and economies Shanghai-China and Singapore, with 14.6% and 12.3%, respectively. Conversely, in 3 OECD countries and 21 partner countries and economies, less than 1% of students are top performers in all 3 domains.

Figure I.3.b shows the proportions of top performers for each country in reading, mathematics and science. Although on average across OECD countries, slightly less than 7% and 1% of 15-year-olds reach Level 5 and Level 6 in reading, respectively, these proportions vary substantially across countries. For example, among OECD countries, New Zealand, Finland, Japan, Korea, Australia, Canada and Belgium have at least 10% of top performers in reading, whereas Mexico, Chile and Turkey have less than 3%. Among the partner countries and economies, the overall proportion of these top performers also varies considerably from country to country, with students in many countries not achieving Level 6 in reading. At the same time, 2 partner countries and economies, Shanghai-China and Singapore, have the highest proportion of students at Level 5. Similar variations are shown in mathematics and science, with only slight differences in the patterns of these results among countries.

Among countries with similar mean scores in PISA, there are remarkable differences in the percentage of top-performing students. For example, Liechtenstein has a mean score of 499 points in reading in PISA 2009 and less than 5% of students at high proficiency levels in reading, which is less than the average of around 8%. Sweden has a similar mean reading score of 497 points, but 9% of its students achieve high proficiency levels in reading, which is more than the average. Although Liechtenstein has a small percentage of students at the lowest levels, the results could indicate the absence of a highly educated talent pool for the future.

Despite similarities across countries for each subject area, a high rank in one subject is no guarantee of a high rank in the others. For example, Switzerland has one of the highest shares of top performers in mathematics, but just an average share of top performers in reading.

Across the three subjects and countries, girls are as likely to be top performers as boys. On average across OECD countries, the proportion of top performers across subject areas is similar between boys and girls: 4.4% of girls and 3.8% of boys are top performers in all three subject areas, and 15.6% of girls and 17.0% of boys are top performers in at least one subject area (see Table I.3.8). However, while the gender gap among students who are top performers is small only in science (1.0% of girls and 1.5% of boys), it is large among top performers in reading only (2.8% of girls and 0.5% of boys) and in mathematics only (3.4% of girls and 6.6% of boys).

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