3

Girls' Lack of Self-Confidence

This chapter examines how girls' lack of self-confidence in their own ability in science and mathematics may be responsible for the observed underachievement among girls in these subjects, particularly among high-achieving girls.

Taken together, the difference in boys' and girls' interests outside of school, and how these interests and skills are rewarded – or not – by teachers and by students' peers, can lead to differences in performance between boys and girls that have little to do with ability (Salisbury et al., 1999).

One factor that may hold girls back is confidence in their own abilities in mathematics. Studies show that the learning environment plays a significant role in fostering, or undermining, girls' sense of self-confidence. Take this example: in one study, Asian-American girls performed better on a mathematics assessment when they were told the reason for doing the test was to identify ethnic differences in performance – because of the stereotype that Asians have higher quantitative skills than other ethnic groups (Steen, 1987) – but worse when they were told that the reason they were asked to take the assessment was to identify gender differences – because of the common stereotype that women are inferior to men in quantitative skills (Aronson, 2002; Benbow, 1988; Hedges and Nowell, 1995) – when compared with a control group that was not given any reason for taking the assessment (Shih et al., 1999).

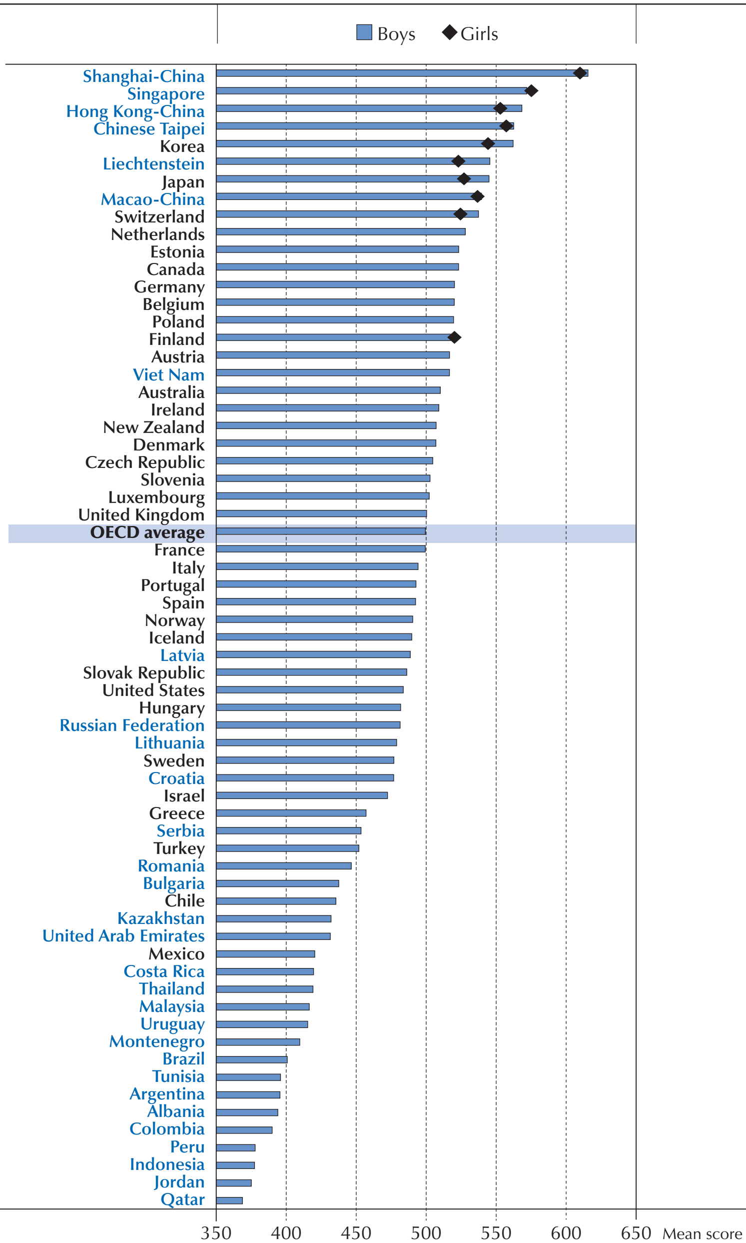
What the data tell us

- On average across OECD countries, mathematics and science self-efficacy (students' beliefs that they can successfully perform given mathematics and science tasks at designated levels) is associated with a difference of 49 score points in mathematics and 37 score points in science – the equivalent of between half and one additional year of school.
- In all countries and economies that participated in PISA 2012, except Albania, Bulgaria, Indonesia, Kazakhstan, Malaysia, Montenegro, Romania, Serbia and Turkey, girls reported stronger feelings of anxiety towards mathematics than boys; and greater mathematics anxiety is associated with a decline in performance of 34 score points – the equivalent of almost one year of school.
- Girls appear to underperform considerably when they are required to "think like scientists". While girls tend to outperform boys on tasks where they are required to identify scientific issues, boys outperform girls in tasks that require them to apply knowledge of science in a given situation, to describe or interpret phenomena scientifically and predict changes, and to identify appropriate scientific descriptions, explanations and predictions.

Results from PISA 2012 confirm that there is no innate reason why girls should not be able to do as well as boys in mathematics. While boys outperform girls in mathematics in 38 participating countries and economies, the average girl in Shanghai-China scores 610 points in mathematics – well above boys' average performance in every other country and school system that participated in PISA and, crucially, just as well as the average boy in Shanghai-China. Similarly, girls in Finland, Macao-China, Singapore and Chinese Taipei perform as well as boys in mathematics – despite the fact that (or maybe because) standards of performance in these countries and economies are among the highest in the world.

■ Figure 3.1 ■

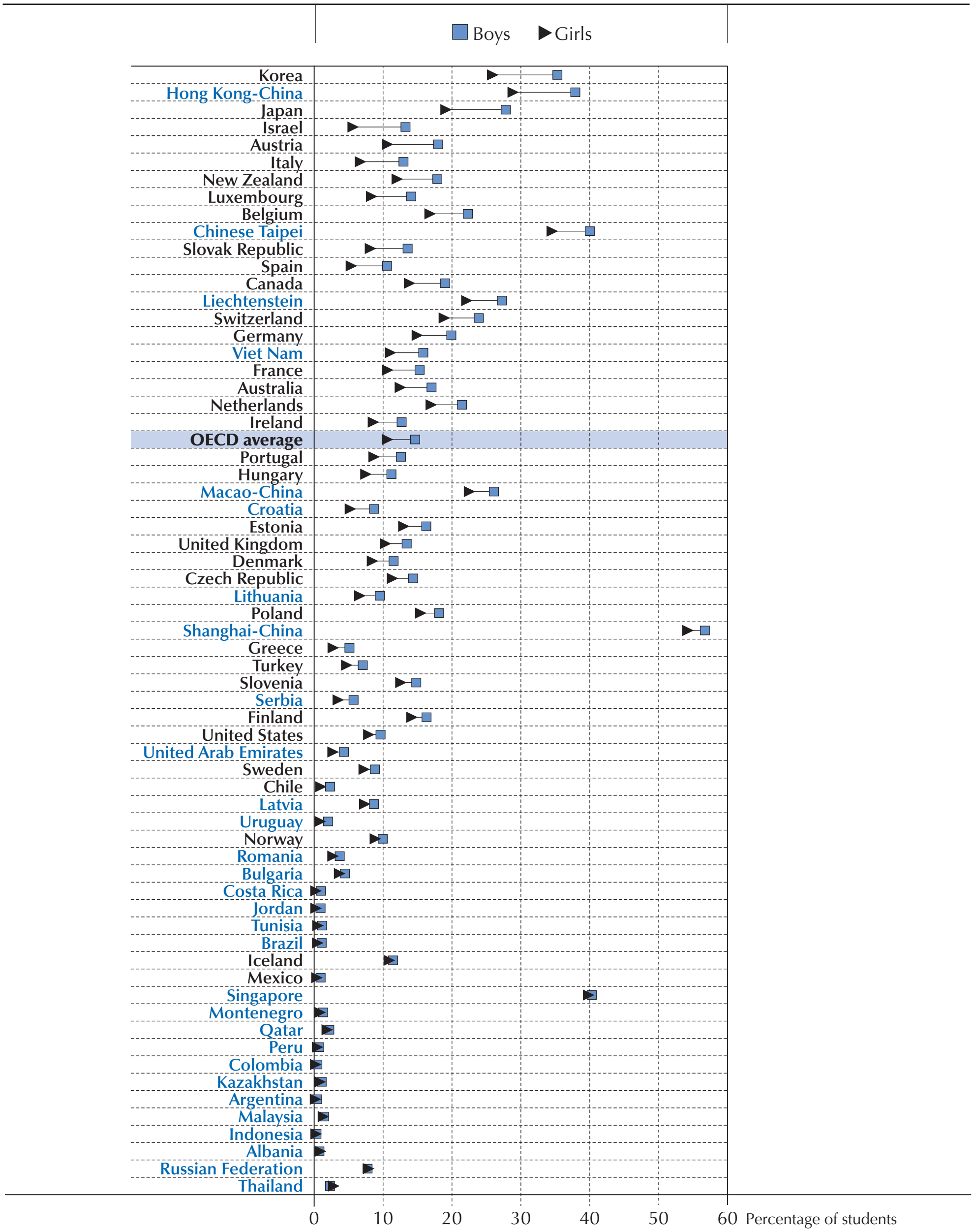
Girls' and boys' average performance in mathematics in the ten countries with the highest average performance among girls



Countries and economies are ranked in descending order of the mean score in mathematics among boys.
Source: OECD, PISA 2012 Database, Table 1.3a.

■ Figure 3.2 ■

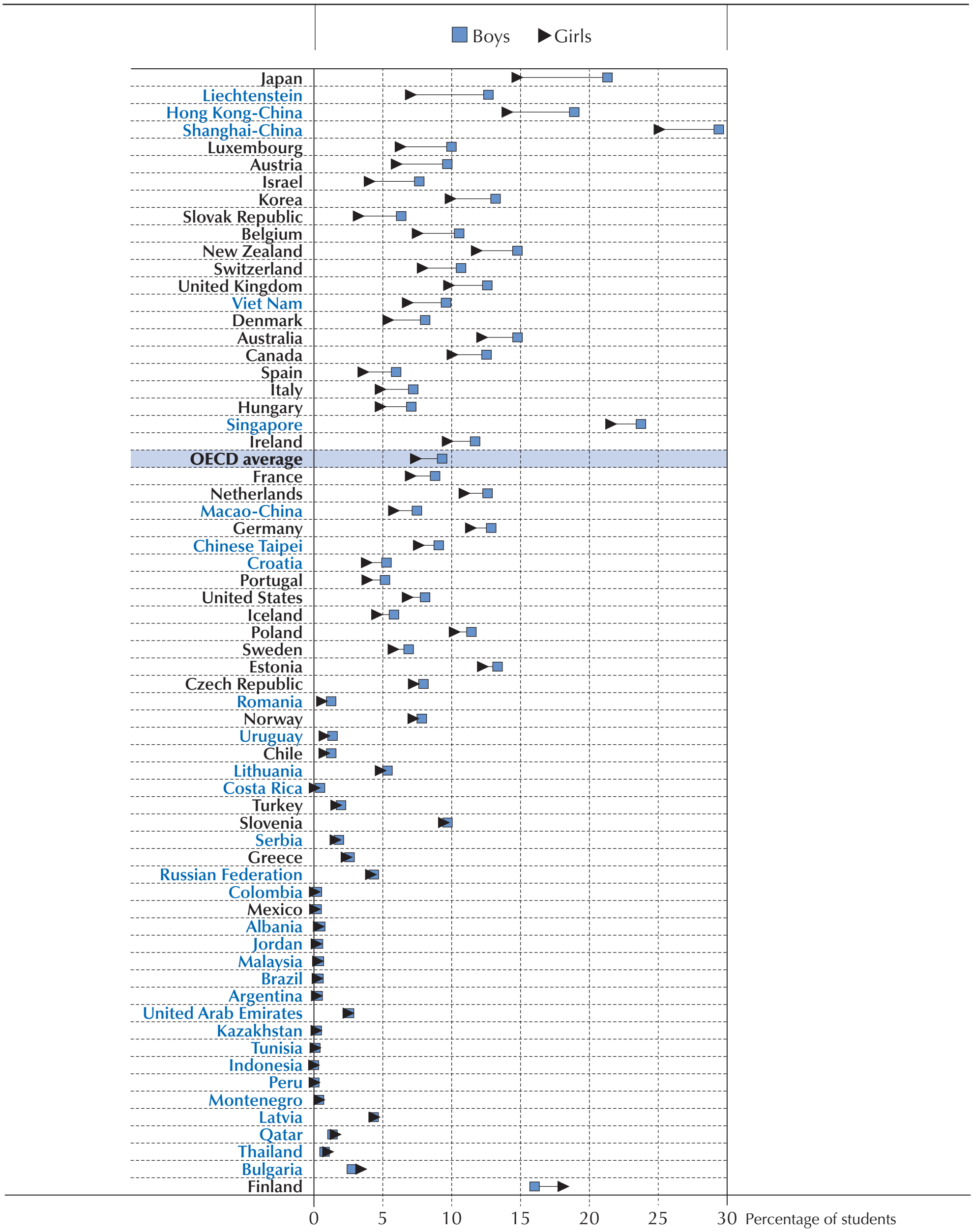
Gender gap among top performers in mathematics



Countries and economies are ranked in descending order of the percentage-point difference between the percentages of boys and girls among top performers in mathematics.
Source: OECD, PISA 2012 Database.

■ Figure 3.3 ■

Gender gap among top performers in science



Countries and economies are ranked in descending order of the percentage-point difference between the percentages of boys and girls among top performers in science.
Source: OECD, PISA 2012 Database.

However, PISA finds that while boys outperform girls in mathematics, on average, in many countries and economies the gender gap is much wider among top-performing students than among low-performing students (Table 1.3a). In the large majority of countries and economies, high-performing girls do worse in mathematics compared to boys; in no country do they outperform boys at this level, and the magnitude of the gender gap is much greater than it is among students at an average level of performance. In science, the highest-achieving boys outperform the highest-achieving girls by an average of 12 score points in as many as 17 OECD countries (Table 1.4a). This is a troubling finding that may be related to the under-representation of women in science, technology, engineering and mathematics (STEM) occupations (Summers, 2005; National Academy of Sciences, 2006; Hedges and Nowell, 1995; Bae et al., 2000). Yet, there are some countries and economies that buck this trend. In Macao-China, Singapore and Chinese Taipei, all of which are high-performers in mathematics, girls perform just as well as boys, even at the highest levels of proficiency. In these countries/economies, there is no gender gap in mathematics performance among the 5% highest-performing students (Table 1.3a).

STUDYING THE "INTANGIBLES" THAT AFFECT LEARNING

So what's going on? To find out, PISA homed in on some of the intangibles that could have an impact on learning, such as students' drive, motivation and self-beliefs. Do these differ significantly between boys and girls? And how are they related to student performance? Some of the starkest differences between boys and girls are only revealed when students express their feelings about their own abilities. PISA and other studies find that girls have less belief in their own abilities in mathematics and science, and are plagued with greater anxiety towards mathematics, than boys – even when they perform just as well as boys. Some studies have found that girls rate their own ability as lower than that of boys as early as the first year of primary school – even when their actual performance does not differ from that of boys (Fredericks and Eccles, 2002; Herbert and Stipek, 2005). What all of this evidence suggests is that gender disparities in drive, motivation and self-beliefs are more pervasive and more firmly entrenched than gender differences in mathematics performance.

How boys and girls think and feel about themselves shapes their behaviour, especially when facing challenging circumstances (Bandura, 1977). Education systems are successful when they equip all students, both boys and girls, with the ability to influence their own lives (Bandura, 2002). Self-beliefs have an impact on learning and performance on several levels: cognitive, motivational, affective and decision-making. They determine how well students motivate themselves and persevere in the face of difficulties, they influence students' emotional life, and they affect the choices students make about coursework, additional classes, and even education and career paths (Bandura, 1997; Wigfield and Eccles, 2000).

This section builds on insights from PISA 2006 in discussing students' self-beliefs in science, and PISA 2012 in discussing students' self-beliefs in mathematics. In 2006, science was the main assessment domain, so the background questionnaire contained a large number of questions on students' attitudes and dispositions towards science. Similarly, in 2012, the main assessment domain was mathematics, and the background questionnaire contained a large number of questions on students' attitudes and dispositions towards mathematics. The science

and mathematics self-beliefs examined include self-efficacy (the extent to which students believe in their own ability to handle mathematical and scientific tasks effectively and overcome difficulties); self-concept (students' beliefs in their own mathematics and science abilities); and intrinsic and instrumental motivation to learn mathematics and science (how much students enjoy learning mathematics and science, and whether they see a value in what they learn for their future careers).

Mathematics and science self-beliefs illustrate students' personal convictions. While they are built into how well students perform in mathematics and science over the course of their lives, once established, they play a determining and independent role in individuals' continued growth and in the development of their mathematical and scientific skills and competencies (Bandura, 1997; Markus and Nurius, 1986). While they are partly the product of a student's past performance in mathematics, biology, physics and chemistry, mathematics and science self-beliefs influence how students function when confronted with mathematical and scientific problems. In addition, they have an independent effect on life choices and decisions. Students who perform similarly in mathematics and in science classes usually choose different courses, education pathways, and ultimately different careers, partly depending on how they perceive themselves as mathematics and science learners (Bong and Skaalvik, 2003; Wang et al., 2013).

Self-efficacy in mathematics and science

Self-efficacy in mathematics and science was measured by asking students about their confidence in being able to solve a series of scientific and mathematical problems. In PISA 2006, students were asked to report whether they believed they could perform a series of tasks either easily or with a bit of effort. These tasks included explaining why earthquakes occur more frequently in some areas than in others; recognising the science question that underlies a newspaper report on a health issue; interpreting the scientific information provided on packages of food; predicting how changes to an environment will affect the survival of certain species; identifying the science question associated with the disposal of garbage; describing the role of antibiotics in treating disease; identifying the better of two explanations of how acid rain is formed; and discussing how new evidence can lead to a change of understanding about the possibility of life on Mars. Students' responses to questions were used to create an *index of science self-efficacy*, which identifies students' level of self-efficacy in science. The index was standardised to have a mean of 0 and a standard deviation of 1 across OECD countries.

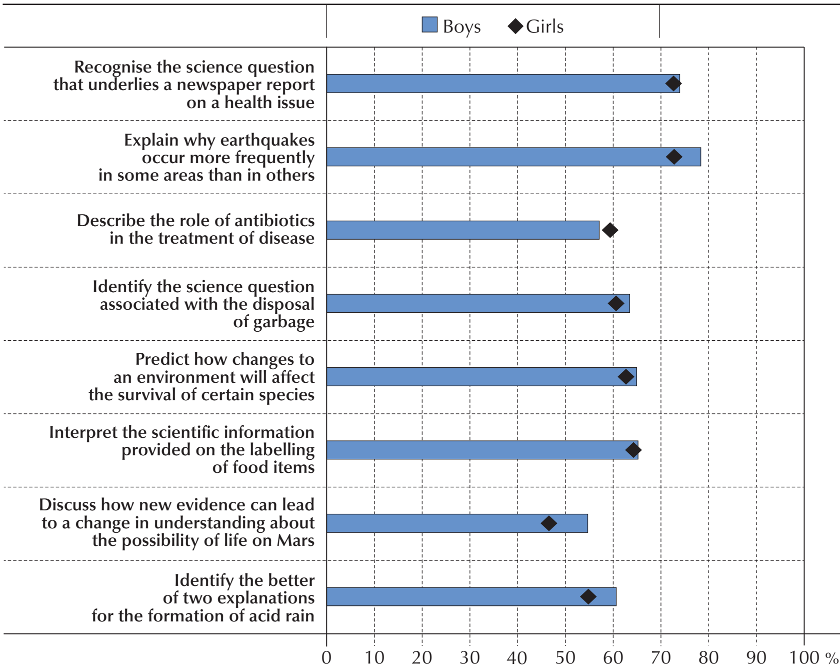
In PISA 2012, students were asked to report on whether they would feel confident doing a range of pure and applied mathematical tasks involving some algebra, such as using a train timetable to work out how long it would take to get from one place to another; calculating how much cheaper a TV would be after a 30% discount; calculating how many square metres of tiles would be needed to cover a floor; calculating the petrol-consumption rate of a car; understanding graphs presented in newspapers; finding the actual distance between two places on a map with a 1:10 000 scale; and solving equations like $3x+5=17$ and $2(x+3)=(x+3)(x-3)$. Students' responses to questions about whether they feel very confident, confident, not very confident or not at all confident were used to create an *index of mathematics self-efficacy*, which identifies students' level of self-efficacy in mathematics. The index was standardised to have a mean of 0 and a standard deviation of 1 across OECD countries.

Tables 3.1b and 3.2b show that while girls, in general, have lower levels of self-efficacy than boys in both mathematics and science, the difference is much wider in mathematics than in science, and the gender gap in feelings of confidence depends greatly on the type of problem or situation boys and girls encounter. For example, boys were more likely than girls to feel confident that they would be able to discuss how new evidence can lead to a change of understanding about the possibility of life on Mars, that they could identify the better of two explanations for how acid rain is formed, and that they could explain why earthquakes occur more frequently in some areas than in others. However, girls reported being more confident than boys in describing the role of antibiotics in treating disease; and there were no large gender differences in how confident boys and girls feel about being able to recognise the science question that underlies a newspaper report on a health issue. Gender differences in science self-efficacy were smaller or even inverted, with girls reporting greater confidence, when scientific issues were framed in the context of health problems (Figure 3.4 and Table 3.1a).

■ Figure 3.4 ■

Gender differences in science self-efficacy

OECD average percentage of students who reported that they can:



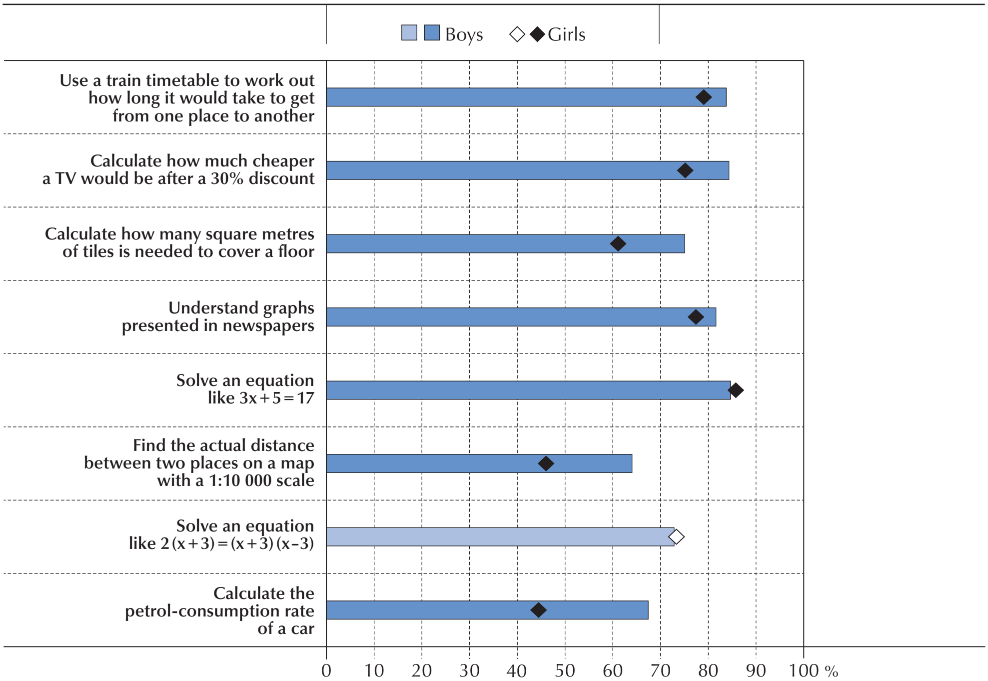
Note: All differences between boys and girls are statistically significant.
Source: OECD, PISA 2006 Database, Table 3.1a.

The same pattern is observed in students' mathematics self-efficacy. Gender differences in self-confidence are particularly large when considering the ability to solve applied mathematics tasks that have gender-stereotypical content. For example, across OECD countries, 67% of boys but only 44% of girls reported feeling confident about calculating the petrol-consumption rate of a car, and 75% of girls (compared to 84% of boys) reported feeling confident or very confident about calculating how much cheaper a TV would be after a 30% discount. However, no gender differences in confidence were observed when students were asked about doing tasks that are more abstract and clearly match classroom content, such as solving a linear or a quadratic equation (Figure 3.5 and Table 3.2a).

■ Figure 3.5 ■

Gender differences in mathematics self-efficacy

OECD average percentage of students who reported that they can:

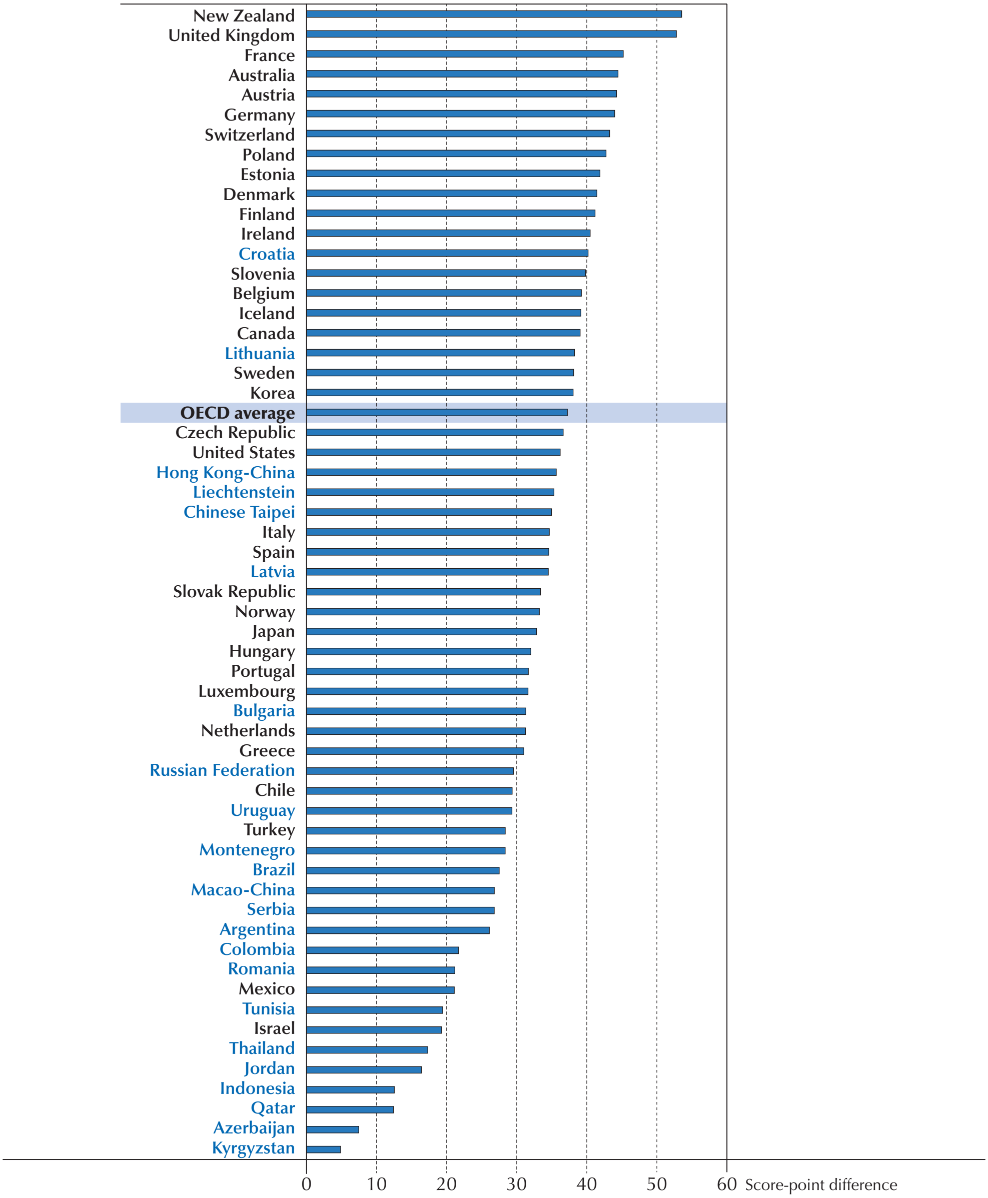


Note: Differences between boys and girls that are statistically significant are marked in a darker tone.
Source: OECD, PISA 2012 Database, Table 3.2a.

While gender differences in mathematics and science self-efficacy, and related beliefs about competence, have long been a subject of study (Eccles, 1984; Jacobs et al., 2002; Pajares and Miller, 1994), there has been no systematic attempt to understand what girls' lack of confidence in their own mathematics abilities means for their countries' future. In fact, PISA reveals that students who have low levels of mathematics and science self-efficacy perform worse in mathematics and science than students who are confident about their ability to handle mathematics and science tasks (Tables 3.1c and 3.2c). On average across OECD countries, mathematics and science self-efficacy are associated with a difference of 49 score points in mathematics and 37 score points in science – the equivalent of between one year and six months of school, respectively.

■ Figure 3.6 ■

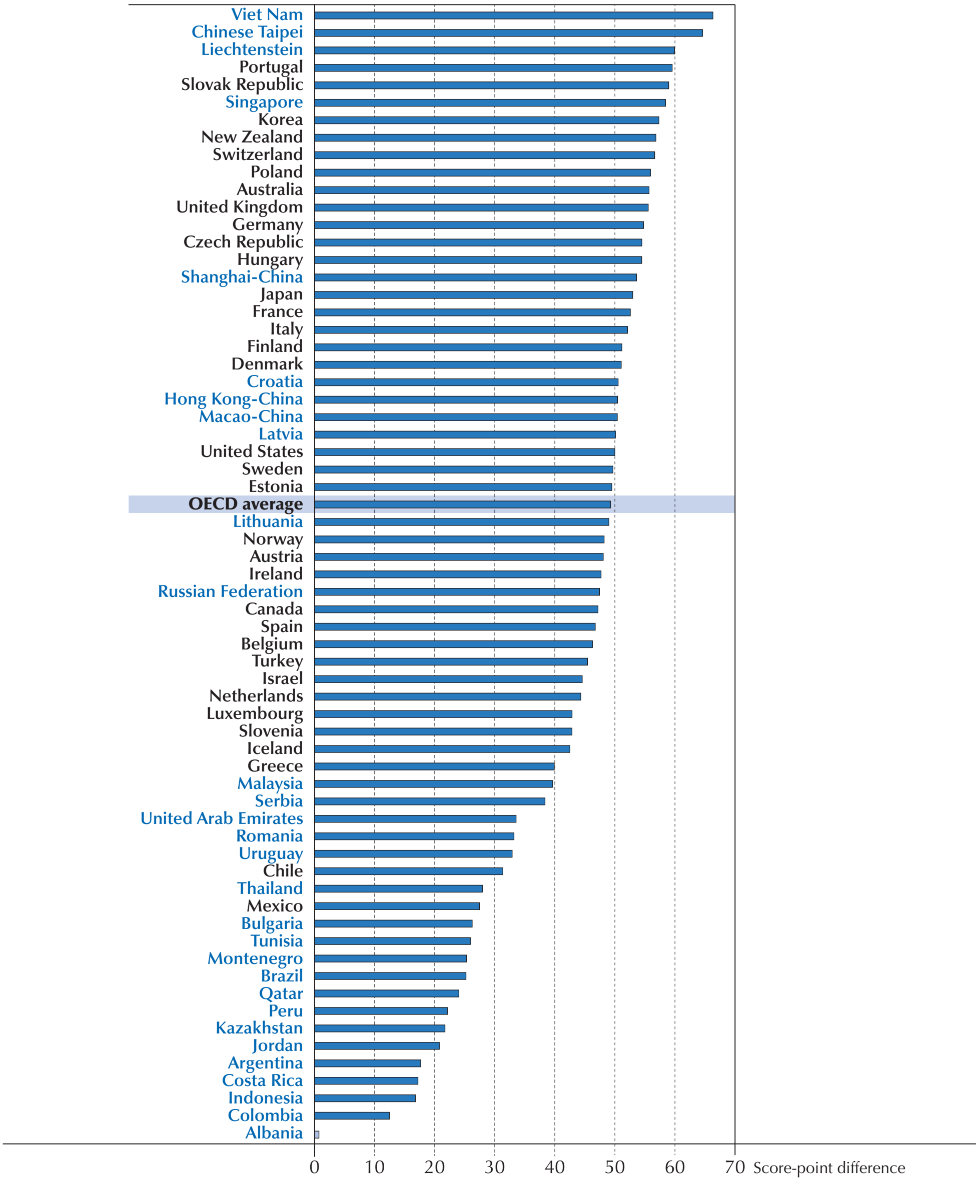
Relationship between science self-efficacy and science performance



Note: All score-point differences are statistically significant.
Countries and economies are ranked in descending order of the score-point difference associated with a one-unit change in the index of science self-efficacy.
Source: OECD, PISA 2006 Database, Table 3.1c.

■ Figure 3.7 ■

Relationship between mathematics self-efficacy and mathematics performance



Note: Score-point differences that are statistically significant are marked in a darker tone.
Countries and economies are ranked in descending order of the score-point difference associated with a one-unit change in the index of mathematics self-efficacy.
Source: OECD, PISA 2012 Database, Table 3.2c.

Self-concept in mathematics and science

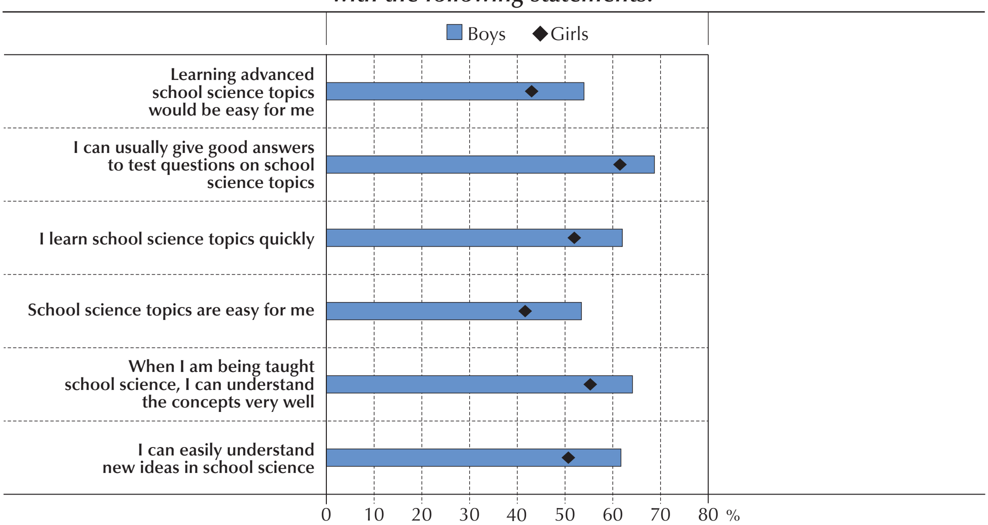
Students' self-concept, or their belief in their own abilities, is an important outcome of education and strongly related to successful learning (Marsh, 1986; Marsh and O'Mara, 2008). Longitudinal studies of self-concept and achievement show that they are reciprocally related over time (Marsh et al., 2012; Marsh and Martin, 2011). Self-concept can also affect well-being and personality development. PISA 2006 measured students' science self-concept through self-reports on whether students strongly agreed, agreed, disagreed or strongly disagreed that they can usually give good answers to test questions on school science topics; that when they are being taught school science, they can understand the concepts very well; that they can learn school science topics quickly; that they can easily understand new ideas in school science; that learning advanced school science topics would be easy for them; and that school science topics are easy for them. Student responses were used to create the *index of science self-concept*, which was standardised to have a mean of 0 and a standard deviation of 1 across OECD countries.

PISA 2012 measured students' mathematics self-concept by using students' responses as to whether they strongly agreed, agreed, disagreed or strongly disagreed that they are just not good in mathematics; that they get good marks in mathematics; that they learn mathematics quickly; that they have always believed that mathematics is one of their best subjects; and that they understand even the most difficult concepts in mathematics class. Student responses were used to create the *index of mathematics self-concept*, which was standardised to have a mean of 0 and a standard deviation of 1 across OECD countries.

■ Figure 3.8 ■

Gender differences in science self-concept

OECD average percentage of students who agreed or strongly agreed with the following statements:



Note: All differences between boys and girls are statistically significant.
Source: OECD, PISA 2006 Database, Table 3.3a.

Figures 3.8 and 3.9 suggest that girls have much lower levels of science and mathematics self-concept. For example, on average across OECD countries, boys were 11 percentage points more likely than girls to agree or strongly agree that learning advanced school science topics would be easy for them; 12 percentage points more likely than girls to agree or strongly agree that school science topics are easy for them; and 11 percentage points more likely than girls to agree or strongly agree that they can easily understand new ideas in school science and easily learn advanced school science topics (Table 3.3a).

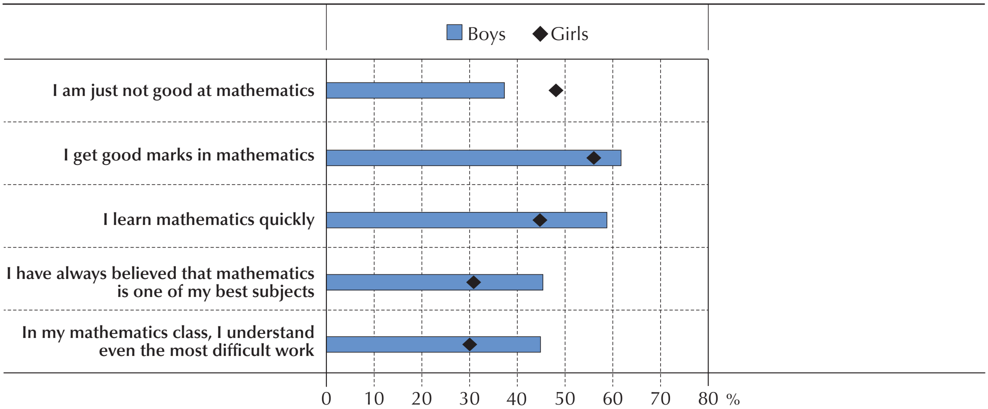
The same pattern is observed in students' mathematics self-concept. Gender disparities in students' mathematics self-concept closely mirror gender disparities in mathematics self-efficacy: 63% of boys, but only 52% of girls, reported that they disagree that they are just not good at mathematics. Conversely, across OECD countries, 30% of girls, but 45% of boys, reported that they understand even the most difficult work in mathematics classes (Table 3.4a). Gender differences in mathematics self-concept are particularly wide in Denmark, Germany, Liechtenstein, Luxembourg, Macao-China and Switzerland, while no such gender differences can be observed in Albania, Kazakhstan and Malaysia (Table 3.2b).

Gender differences in mathematics and science self-efficacy and self-concept remain large even among students who perform at the same level in mathematics and science. Girls who perform as well as boys reported much lower levels of mathematics and science self-efficacy and lower levels of mathematics and science self-concept. These results are in line with previous empirical estimates (Jacobs et al., 2002). On average across OECD countries, girls are over one-quarter of a standard deviation lower on the self-beliefs indices than boys.

■ Figure 3.9 ■

Gender differences in mathematics self-concept

OECD average percentage of students who agreed or strongly agreed with the following statements:



Note: All differences between boys and girls are statistically significant.
Source: OECD, PISA 2012 Database, Table 3.4a.

Anxiety towards mathematics

While many students worry about their performance in school and are anxious when they have to take exams, large proportions of students report feeling anxious about mathematics in particular (Ashcraft and Ridley, 2005; Hembree, 1990; Wigfield and Meece, 1988). Students who have high levels of mathematics anxiety generally report feeling tense, apprehensive and fearful of mathematics (Richardson and Suinn, 1972; Ma, 1999; Zeidner and Matthews, 2011; Tobias, 1993); and they tend to underperform in mathematics tasks compared to students with no or low levels of mathematics anxiety (Hembree, 1990; Ma, 1999; Tobias, 1985).

While poor performance in mathematics tends to be associated with high mathematics anxiety (Ma and Kishor, 1997; Ma and Xu, 2004), evidence indicates that part of the performance gap between students with high and low levels of mathematics anxiety is directly related to the adverse effect of anxiety on cognitive resource activation (Ashcraft and Kirk, 2001). In other words, when students are anxious, in general, and are anxious about mathematics, in particular, their brains cannot devote sufficient attention to solving mathematics problems because they are, instead, occupied with worrying about such tasks (Beilock et al., 2004; Hopko et al., 1998; Hopko et al., 2002; Kellogg et al., 1999). Mathematics anxiety is not merely a psychological phenomenon; students who experience mathematics anxiety generally avoid mathematics, mathematics courses and career paths that require the mastery of some mathematical skills (Hembree, 1990; Ashcraft and Ridley, 2005; Beasley, Long and Natali, 2001; Ho et al., 2000).

PISA 2012 asked participating boys and girls to report whether they agree or strongly agree that they often worry that mathematics classes will be difficult for them; that they get very tense when they have to do mathematics homework; that they get very nervous doing mathematics problems; that they feel helpless when doing a mathematics problem; and that they worry that they will get poor marks in mathematics. Student responses about their feelings of stress associated with anticipating mathematical tasks, anticipating their performance in mathematics, and while attempting to solve mathematics problems were used to identify students' specific level of anxiety about mathematics and to construct an *index of mathematics anxiety*, standardised to have a mean of 0 and a standard deviation of 1 across OECD countries. Positive values on the index indicate that students reported higher levels of anxiety about mathematics than the average student across OECD countries, while negative values indicate that students reported lower levels of anxiety about mathematics than the average student across OECD countries.

While a considerable proportion of 15-year-olds reported feelings of helplessness and emotional stress when dealing with mathematics, girls were consistently more likely than boys to report feelings of anxiety towards mathematics (Table 3.2b). In all countries and economies that participated in PISA 2012, except Albania, Bulgaria, Indonesia, Kazakhstan, Malaysia, Montenegro, Romania, Serbia and Turkey, girls reported stronger feelings of mathematics anxiety than boys. Only in Jordan, Qatar and the United Arab Emirates did boys report greater feelings of anxiety than girls (Table 3.2b). Gender differences in mathematics anxiety tended to be particularly wide in Denmark and Switzerland. Overall, the gender difference in mathematics anxiety appears to be largest in those countries that have comparatively low levels of mathematics anxiety.

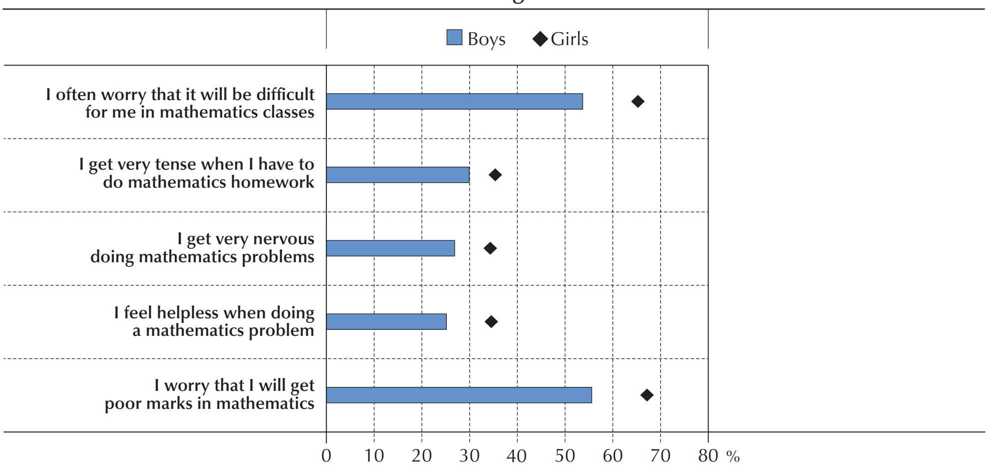
This means that while some education systems have been able to reduce greatly the number of boys who feel anxious towards mathematics, they have not been as successful with girls.

On average across OECD countries, greater mathematics anxiety is associated with a decline in performance of 34 score points – the equivalent of almost one year of school – and the gap in scores is even larger among high achievers.

■ Figure 3.10 ■

Gender differences in mathematics anxiety

OECD average percentage of students who agreed or strongly agreed with the following statements:



Note: All differences between boys and girls are statistically significant.
Source: OECD, PISA 2012 Database, Table 3.5a.

UNDERPERFORMING AT THE TOP

PISA cannot determine cause, but the strong relationship among self-beliefs, gender and performance in mathematics and science hints that countries may be unable to develop a sufficient number of individuals with strong mathematics and science skills partly because of girls' lack of confidence in their abilities. This may be exacerbated by the fact that the relationship between greater mathematics and science self-belief and higher performance is particularly strong among the highest-performing students. Greater self-efficacy, for example, is less closely related to the performance of the lowest-achieving students than to that of the highest-achieving students. A difference of one unit on the *index of mathematics self-efficacy* is associated with a 43 score-point difference in performance among the 10% lowest-performing students, but with a 53 score-point difference in performance among the 10% highest-performing students (Table 3.2c). Similarly, a difference of one unit on the *index of science self-efficacy* is associated with a 30 score-point difference in performance among the 10% lowest-performing students, but with a 41 score-point difference in performance among the 10% highest-performing students (Table 3.1c).

What emerges from these analyses is particularly worrying. Even many high-achieving girls have low levels of confidence in their ability to solve science and mathematics problems and express high levels of anxiety towards mathematics. Results presented in Tables 3.1b and 3.2b indicate that even among boys and girls who are equally capable in mathematics and science, girls tend to report lower levels of subject-specific self-efficacy and self-concept. This means that while girls' lower performance in mathematics and science among the highest-achieving students may reflect lower levels of self-confidence and higher levels of anxiety, the differences in levels of self-confidence and anxiety between boys and girls are greater than differences in mathematics and science performance.

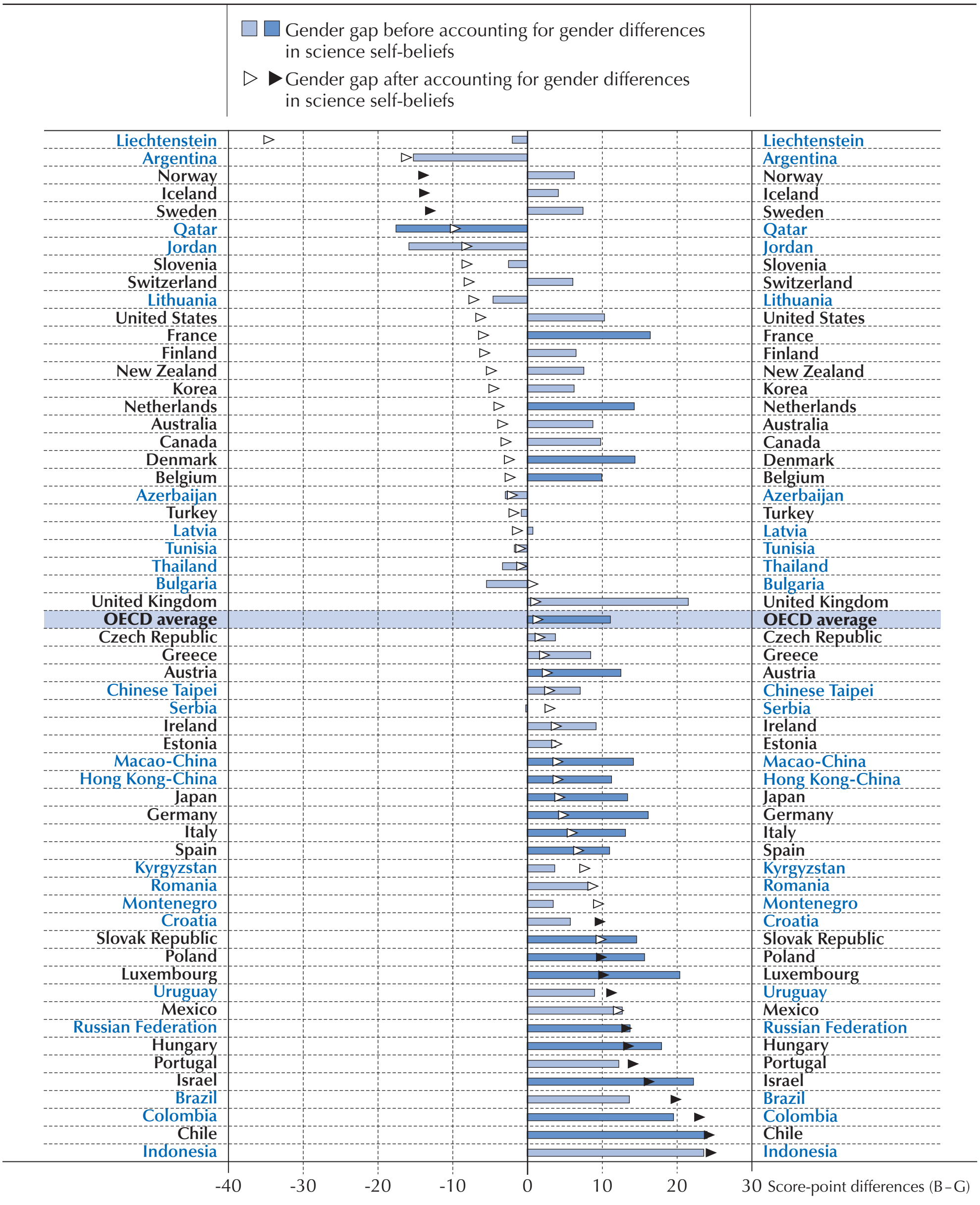
Results in Chapter 1 of this report and Tables 3.1c, 3.2c, 3.3b and 3.4b show that while boys outperform girls in mathematics, on average, in many countries and economies, the gender gap in science performance between the average boy and the average girl differs across countries. However, even in science there is a sizeable gap in favour of boys among top-performing students. This is a troubling finding, as some believe it is responsible for the under-representation of women in STEM occupations (Summers, 2005; National Academy of Sciences, 2006; Hedges and Nowell, 1995; Bae et al., 2000).

The findings shown in Figure 3.11 also suggest that differences in students' reported levels of science self-beliefs, such as science self-efficacy and science self-concept, also explain a large share of the gender gap in science performance among the highest-achieving students (Table 3.6a). This gender gap is significant in only 12 countries and economies after differences in science self-efficacy and self-concept are taken into account. In most of the remaining countries, the gender gap in science scores shrinks considerably after accounting for differences in self-reported levels of science self-beliefs. In Iceland, Norway and Sweden, high-achieving girls outperform high-achieving boys with similar levels of science self-concept and self-efficacy. On average across OECD countries, before accounting for gender differences in science self-concept and self-efficacy, there is an 11 score-point difference in performance between high-achieving girls and high-achieving boys. But when comparing high-achieving boys and girls who reported similar levels of science self-beliefs, there is no performance gap.

The data shown in Figure 3.12 suggest that differences in students' reported levels of mathematics self-beliefs explain a large share of the gender gap in performance among the highest-achieving students, and show a similar relationship between science self-beliefs and science performance. On average across OECD countries, the score-point difference in mathematics performance between high-achieving girls and boys is 20 score points. However, when comparing boys and girls who also reported similar levels of mathematics self-efficacy, self-concept and mathematics anxiety, there is no performance gap. The data shown in Figure 3.12 indicate that, when the highest-achieving students have similar levels of mathematics self-beliefs, girls underperform compared to boys in only six countries. By contrast, before these differences in self-beliefs are taken into account, 40 countries and economies show a gender gap in mathematics performance. Even in those countries where high-achieving girls underperform compared with high-achieving boys, the gender gap is considerably narrower when comparing boys and girls who reported the same levels of mathematics self-beliefs (Table 3.6b).

■ Figure 3.11 ■

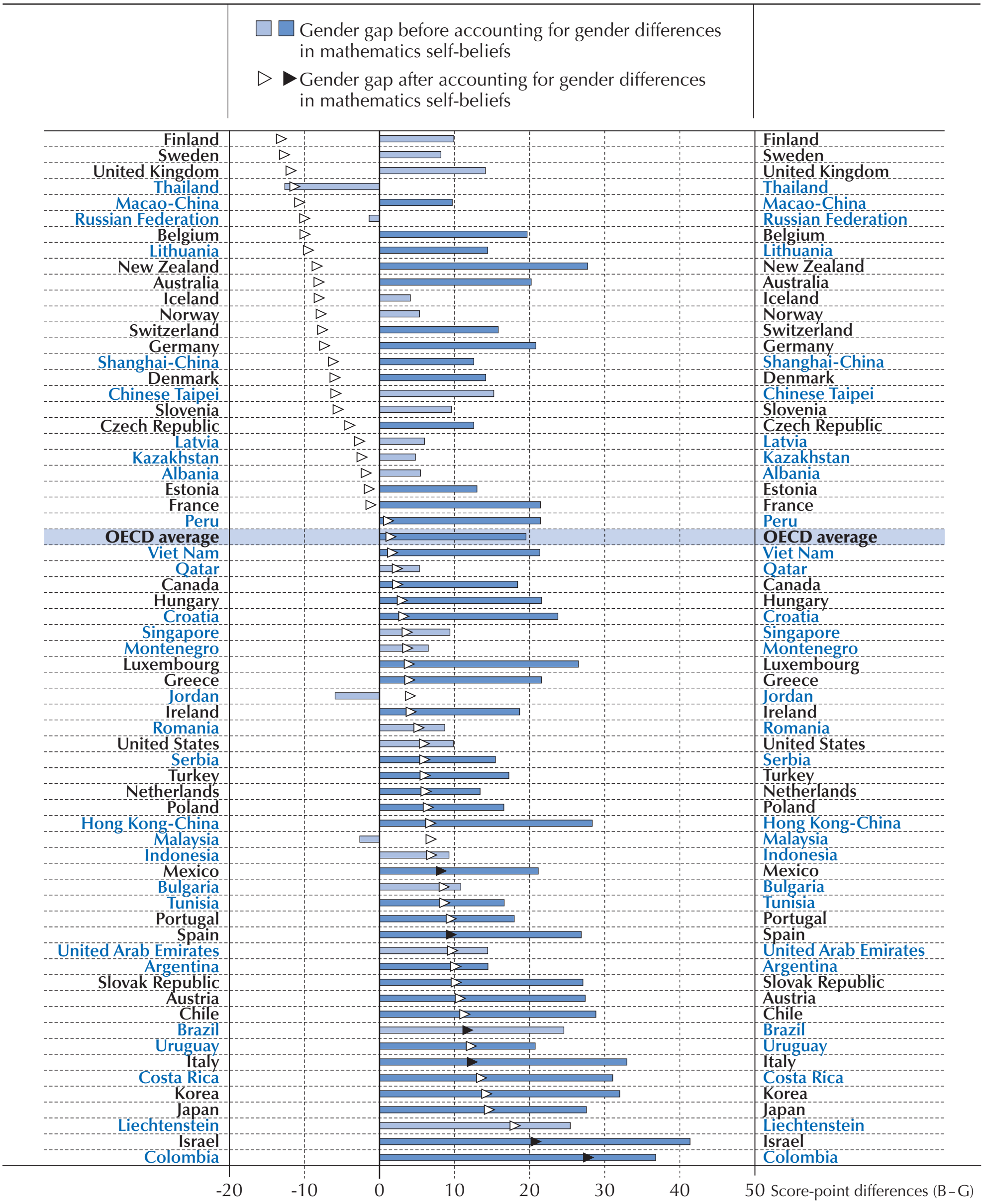
Role of science self-beliefs in reducing the gender gap among the highest-achieving students



Note: Score-point differences between boys and girls that are statistically significant are marked in a darker tone.
Countries and economies are ranked in ascending order of the score-point difference after accounting for gender differences in science self-beliefs.
Source: OECD, PISA 2006 Database, Table 3.6a.

■ Figure 3.12 ■

Role of mathematics self-beliefs in reducing the gender gap among the highest-achieving students



Note: Score-point differences between boys and girls that are statistically significant are marked in a darker tone.
Countries and economies are ranked in ascending order of the score-point difference after accounting for gender differences in mathematics self-beliefs.
Source: OECD, PISA 2012 Database, Table 3.6b.

Gender disparities in mathematics and science achievement might also result from differences in the opportunities boys and girls have to practice their math and science skills, such as in mathematics-related work outside of school (Fryer and Levitt, 2010; Wang, 2012), or from differences in the schools in which they are enrolled, and the courses they choose or are streamed into while at school. If girls invest less time than boys studying mathematics and science because they hold negative self-beliefs about these subjects, or because they are less encouraged by teachers and parents to invest their effort in mathematics and science rather than in other subjects, then a gender gap in mathematics and science performance could open by the time students reach adolescence.

Results presented in Tables III.4.5c and III.7.4 in Chapters 4 and 7 of *Ready to Learn: Students' Engagement, Drive and Self-Beliefs* (OECD, 2013) indicate that participation in mathematics-related activities, such as playing chess, programming computers, taking part in mathematics competitions, or helping friends with mathematics problems, does not explain why boys and girls are not equally likely to perform at high levels in mathematics. The gender gap, whether at the mean, bottom or top of the performance distribution, remains unchanged, whether or not gender differences in participation in mathematics-related activities are taken into account. This might simply indicate that these are not the types of activities that could help girls achieve at higher levels. While PISA data cannot be used to measure the amount of time boys and girls invested in studying mathematics and science up until the moment they took the PISA test, they can be used to identify gender differences in participation in the kinds of courses and activities that may help students to become more familiar with the two subjects.

OPPORTUNITY TO LEARN MATHEMATICS

One of the reasons why boys and girls may develop different levels of mathematics skills may be because they are offered, or take advantage of, different opportunities to learn mathematics in and outside of school. For example, girls are less likely than boys to play chess, program computers, take part in mathematics competitions, or do mathematics as an extracurricular activity (Table 3.7). On average across OECD countries, the proportion of girls who play chess is 12 percentage points smaller than the proportion of boys who do, and the proportion of girls who program computers is 14 percentage points smaller that the share of boys who do. These activities stimulate logical thinking and can be a fun way of using mathematical skills and abilities in play-like situations.

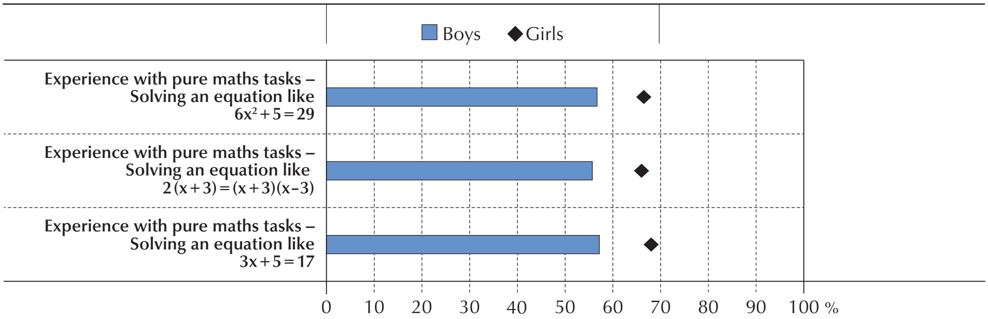
Girls and boys appear to have different levels of exposure to certain mathematics problems and concepts. As Tables 3.8a, 3.8b, and 3.8c show, girls appear to be overwhelmingly more likely than boys to report that they frequently encounter pure mathematics problems. On average across OECD countries, in 2012, 66% of girls but only 57% of boys reported that they frequently encounter a quadratic equation like $6x^2+5=29$. In all countries and economies except Albania, Colombia, Liechtenstein and New Zealand, girls were more likely than boys to have reported that they encounter this type of quadratic equation. Similarly, girls were more likely than boys, on average across OECD countries, to have reported that they had to solve the following equation: $2(x+3)=(x+3)(x-3)$. While 66% of girls, on average, reported that they have frequently been asked to solve such an equation at school, only 56% of boys reported the same.

Gender differences are also very large in how frequently boys and girls are asked to solve a linear equation like 3x+5=17. While 68% of girls, on average, reported that they have frequently been asked to do so, only 57% of boys reported the same.

■ Figure 3.13 ■

Gender differences in students' experience with pure mathematics tasks

OECD average percentage of students who reported:

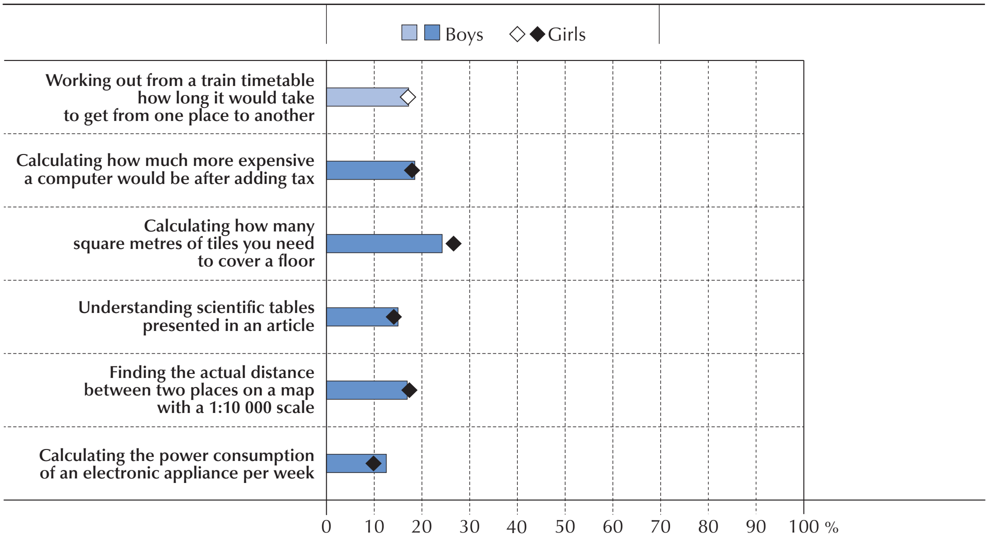


Note: All differences between boys and girls are statistically significant.
Source: OECD, PISA 2012 Database, Table 3.8a.

■ Figure 3.14 ■

Gender differences in students' experience with applied mathematics tasks

OECD average percentage of students who reported having experience in:



Note: Differences between boys and girls that are statistically significant are marked in a darker tone.
Source: OECD, PISA 2012 Database, Table 3.8a.

Figure 3.13 and Table 3.8a show that while girls appear to be overwhelmingly more likely than boys to have reported that they have encountered pure mathematics tasks, such as solving quadratic and linear equations, gender differences in reported experience with applied mathematics tasks are generally very small; in fact, in the large majority of countries and economies there is no difference in boys' and girls' exposure to such tasks. On average across OECD countries, in 2012, 17% of boys and girls reported that they have frequently encountered a problem like one requiring them to look at a train timetable and determine how long it would take to get from one place to another (Figure 3.14 and Table 3.8a). Similarly, the gender gap in the percentage of boys and girls who reported that they have frequently been asked to calculate how much more expensive a computer would be after adding tax is less than 1 percentage point, on average across OECD countries.

PISA 2012 asked participating students to report how familiar they are with a number of mathematics concepts and terms. Students were asked to report whether they never heard the concept, heard it only once or twice, heard it a few times, heard it often, or know it well and understand the concept. Among a series of geometry, algebra and statistics terms, students were asked to report their level of familiarity with three concepts that do not exist, to capture potential differences in response style and "overclaiming", since some students may report being familiar with some concepts when they are not.

Figure 3.15 and Table 3.8b show the percentage of boys and girls who reported that they have heard often or know and understand a concept well. Results indicate that girls were much more likely than boys to report that they heard often and are familiar with most concepts, except for the three concepts that do not exist. For example, on average across OECD countries, 68% of girls and 65% of boys reported a high level of familiarity with *divisors*. Similarly, 54% of both girls and boys reported a high level of familiarity with *quadratic functions*. However, 15% of boys and 11% of girls reported being familiar with the non-existent item *declarative fractions*, and 12% of boys but only 7% of girls reported being very familiar with the non-existent item *subjunctive scaling*.

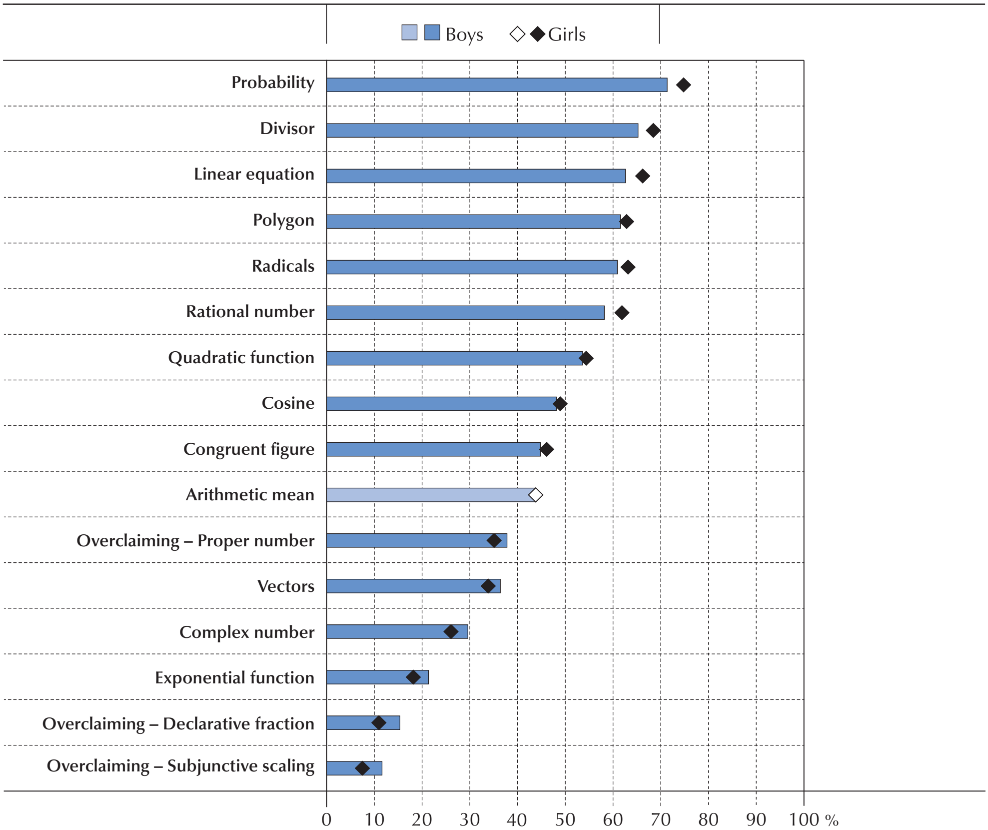
Differences in overclaiming between boys and girls suggest that gender differences in levels of familiarity with mathematics concepts may be more profound than what students' self-reports suggest, because boys have a tendency to report that they are familiar with topics even though they are not. Table 3.8c shows aggregate results on gender differences in the three indices that were developed based on students' responses to questions concerning exposure to pure and applied mathematics tasks and familiarity with mathematics concepts, after accounting for overclaiming by individual students. All indices are standardised to have a mean of 0 and a standard deviation of 1 across OECD countries.

Girls are more likely than boys to be familiar with a broad array of formal mathematics concepts, ranging from algebra to geometry, and to have been asked to solve pure mathematics tasks, such as solving a linear or a quadratic equation. Gender differences in students' reports of the frequency with which they encounter applied mathematics tasks are much smaller and differ across countries.

■ Figure 3.15 ■

Gender differences in students' familiarity with formal mathematics

OECD average percentage of students who reported being familiar with the following concepts:

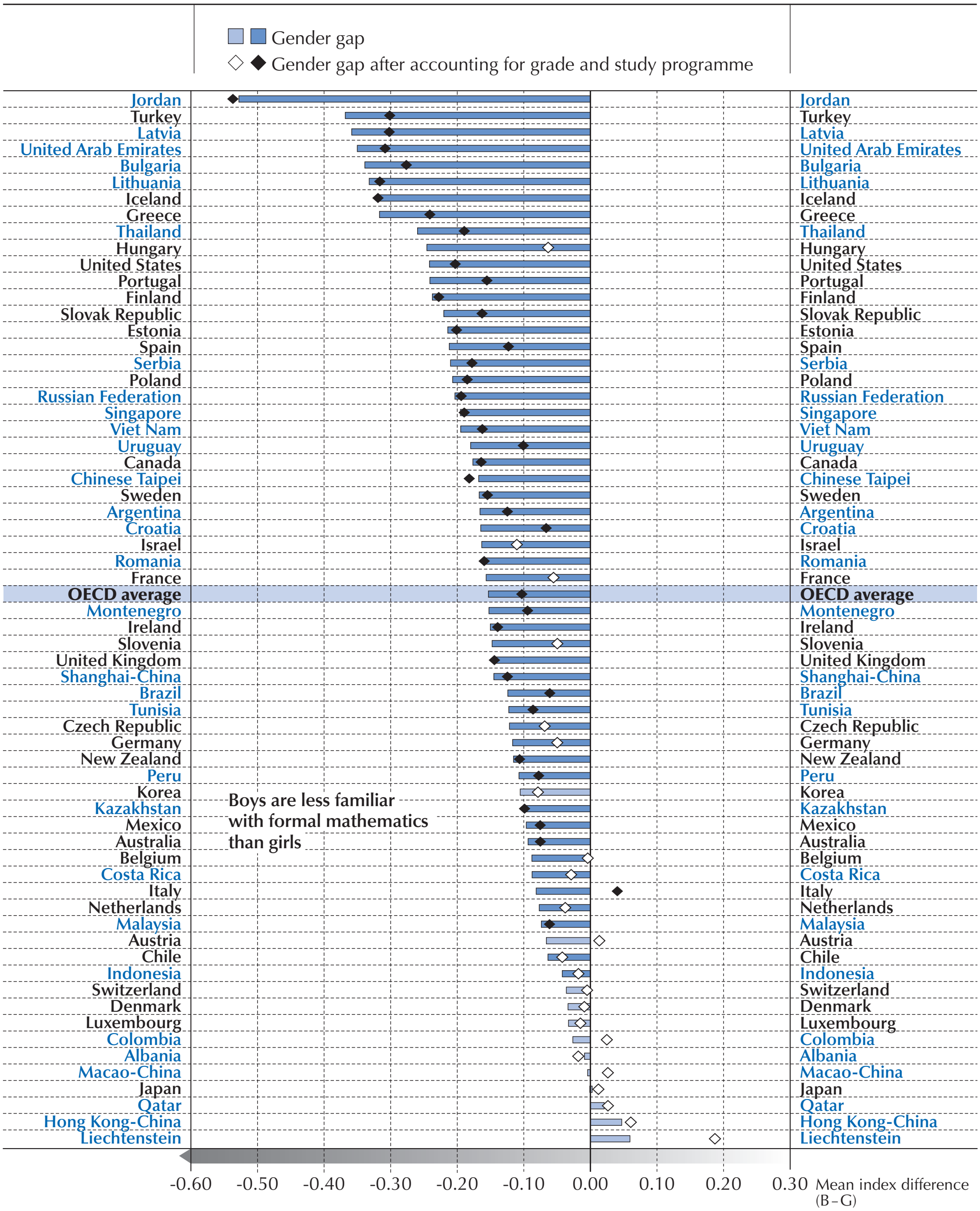


Note: Differences between boys and girls that are statistically significant are marked in a darker tone.
Concepts are ranked in descending order of the percentage of boys who reported that they are very familiar with each (have either heard often or know well and understand a given concept).
Source: OECD, PISA 2012 Database, Table 3.8b.

Differences between boys and girls in exposure to pure mathematics tasks and familiarity with formal mathematics concepts may be due to the fact that boys are more likely than girls to repeat grades (see Table 2.13b) such that, at the same age, they may be less likely than girls to have covered specific mathematical concepts and problems. Boys are also more likely than girls to attend vocational schools (see Table 4.1), and these schools may favour a more applied approach to the study of mathematics (as well as other subjects). Results presented in Table 3.8c show the gender gap in familiarity with formal mathematics, and experience with pure and applied mathematics, when controlling for the grade students are in, and whether students attend vocational or pre-vocational programmes rather than academic-oriented or modular programmes.

■ Figure 3.16 ■

Role of grade repetition and study programme in explaining gender differences in students' familiarity with formal mathematics



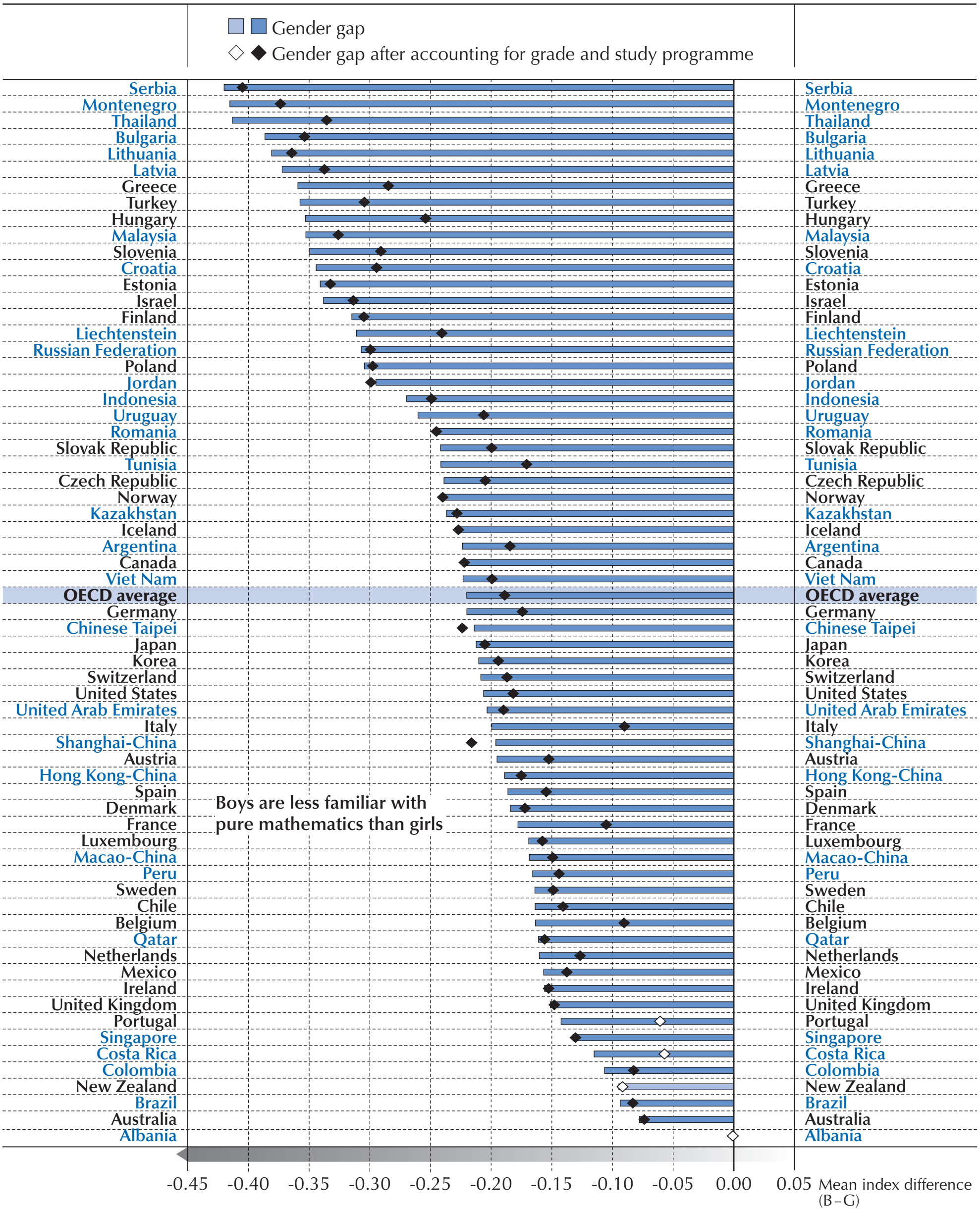
Note: Gender differences that are statistically significant are marked in a darker tone.

Countries and economies are ranked in ascending order of the gender gap related to students' familiarity with formal mathematics (before accounting for grade and study programme).

Source: OECD, PISA 2012 Database, Table 3.8c.

■ Figure 3.17 ■

Role of grade repetition and study programme in explaining gender differences in students' experience with pure mathematics tasks



Note: Gender differences that are statistically significant are marked in a darker tone.
Countries and economies are ranked in ascending order of the gender gap related to students' experience with pure mathematics tasks (before accounting for grade and study programme).
Source: OECD, PISA 2012 Database, Table 3.8c.

Results indicate that differences in students' grade level and study programme explain only a small part of the differences between boys and girls in how familiar they are with formal mathematics and with pure mathematics tasks. On average across OECD countries, around one-third of the gender gap in students' level of familiarity with formal mathematics is explained by grade and study programme. Similarly, even though grade and study programme explain some of the gender gap in students' experience with pure mathematics tasks, this gap remains large and significant after accounting for these factors. Girls in all OECD countries, except New Zealand and Portugal, and in all partner countries and economies, except Albania and Costa Rica, reported having had greater experience with pure mathematics problems, such as solving a linear or a quadratic equation (Table 3.8c). Similarly, in 17 OECD countries girls reported greater familiarity with a range of mathematics concepts; Italy is the only OECD country in which boys reported greater familiarity with mathematics concepts than girls.

These differences are important because familiarity with formal mathematics and experience with pure mathematics are strongly and positively associated with performance in mathematics. Table 3.8d shows the change in mathematics score that is associated with a one-unit change on the *index of familiarity with formal mathematics*, the *index of experience with pure mathematics problems*, and the *index of experience with applied mathematics problems*. When not considering other factors, a difference of one unit on the *index of familiarity with formal mathematics* is associated with a difference of 41 score points in mathematics, on average across OECD countries, and a difference of one unit in the *index of experience with pure mathematics problems* is associated with a difference of 30 score points (Table 3.8d). When considering all aspects of opportunity to learn in mathematics simultaneously, the score-point difference associated with familiarity with mathematics concepts is 36 points and that associated with experience with pure mathematics is 23 points.

What is particularly interesting is that the gender gap in mathematics performance is considerably larger when boys' and girls' different levels of familiarity with mathematics concepts, and their experience with pure and applied mathematics, are considered (Table 3.8d). On average across OECD countries, the gender gap in mathematics performance stands at 11 score points, but is 22 points among boys and girls who reported similar levels of familiarity with mathematics concepts and experience with pure and applied mathematics problems.

The difference in the gender gap before and after taking into account opportunities to learn mathematics is large (11 score points, on average across OECD countries) and is significant in as many as 30 OECD countries and 25 partner countries and economies. These results suggest that, in many countries, girls' performance in mathematics is closer to that of boys thanks to the greater effort they invest in their mathematics studies. In Jordan, Lithuania and Turkey, the gender gap narrows by 20 score points in mathematics because of girls' greater investment in mathematics classes. Albania, Austria, Costa Rica, Denmark, Japan, Liechtenstein, Macao-China and Romania are the only countries/economies where the difference in the gender gap before and after accounting for opportunities to learn mathematics is not significant (Table 3.8d).

Results presented in Table 3.8e, however, reveal that in the large majority of countries and economies, students' familiarity with mathematics concepts and experience with pure mathematics tasks are as strongly associated with mathematics performance among low-achieving students as they are among high-achieving students. On average across OECD countries, a change of one unit on the *index of familiarity with formal mathematics* is associated with a difference of 32 score points in mathematics performance among the 10% lowest-performing students and a difference of 36 score points among the 10% highest-performing students. Similarly, a change of one unit on the *index of experience with pure mathematics tasks* is associated with a difference of 24 score points in mathematics performance among the 10% lowest-performing students and a difference of 20 score points among the 10% highest-performing students. Interestingly, differences in experience with pure and applied mathematics tasks and familiarity with formal mathematics concepts do not explain why girls perform worse in mathematics than boys, particularly among the highest-achieving students.

CHOKING UNDER PRESSURE

As discussed above, girls at every proficiency level in mathematics and science tend to report greater anxiety towards mathematics and lower levels of self-efficacy and self-concept. Chapter 2 also suggests that girls are more likely than boys to be engaged with school, put effort into their studies, and believe that school is important. It is possible that girls' greater motivation to do well in school and the greater investment they make to achieve this goal are undermined by their lack of self-confidence in scientific subjects, particularly when girls are capable of achieving at the highest levels (Beilock and Carr, 2001).

In professional sports, the phenomenon is known as choking under pressure. Paradoxically, a supportive environment, such as being the home team in a crucial game, can sap top athletes of precisely the skills that make them great (Baumeister and Steinhilber, 1984; Baumeister, 1984). The fear of letting others down, making mistakes and underachieving may lead some high-achieving individuals to focus on the minutiae of what they're doing rather than on the situation at hand and how best to respond to it (Beilock and Carr, 2001; Oudejans et al., 2011). While self-awareness and step-by-step control of actions are associated with better performance among low- and average-achieving individuals, they actually disrupt performance among the highest achievers.

Girls may be "choking under pressure" in mathematics. High-achieving girls are more likely to suffer from high levels of anxiety than high-achieving boys, even when they have greater intrinsic motivation to learn mathematics. PISA measures students' intrinsic motivation to learn mathematics through their responses ("strongly agree", "agree", "disagree" or "strongly disagree") to statements asserting that they enjoy reading about mathematics; that they look forward to mathematics lessons; that they do mathematics because they enjoy it; and that they are interested in the things they learn in mathematics.

Results presented in Table 3.10 suggest that individuals who are anxious about mathematics tend to have less intrinsic motivation to learn mathematics, and vice-versa; but among boys and girls who have similar levels of intrinsic motivation to learn mathematics, girls tend to be consistently more anxious towards mathematics than boys. On average across OECD countries, among boys and girls with similar levels of intrinsic motivation to learn mathematics, girls are one-tenth of a standard deviation higher on the *index of mathematics anxiety* than boys. Crucially, these results also indicate that when students are intrinsically motivated to learn mathematics, but are anxious towards the subject, their performance suffers.

THINKING LIKE A SCIENTIST

Results from the PISA 2012 mathematics and problem-solving assessments and the PISA 2006 science assessment suggest that girls' performance tends to be better in areas where they are required to apply mathematics concepts, facts, procedures and reasoning, and to recognise scientific issues. However, girls appear to underperform considerably when they are required to think like scientists – meaning when they are asked to formulate problems mathematically, interpret phenomena scientifically and predict changes, solve interactive problems, or understand and solve problems where the way of solving the problem is not immediately obvious and the problem evolves over time.

Gender differences in mathematics performance, in favour of boys, are particularly pronounced when students are required to translate a word problem into a mathematical expression. On average across OECD countries, boys outperform girls on the *formulating* subscale by around 16 points, while the average gender gap in the PISA mathematics test as a whole is 11 score points. Among OECD countries, the largest differences in favour of boys are observed in Austria, Chile, Italy, Korea, Luxembourg and New Zealand. In the United States, the gender difference was less than 10 points. Only one country shows a performance difference in favour of girls: Qatar (9 points) (Tables 1.3a and 1.10a).

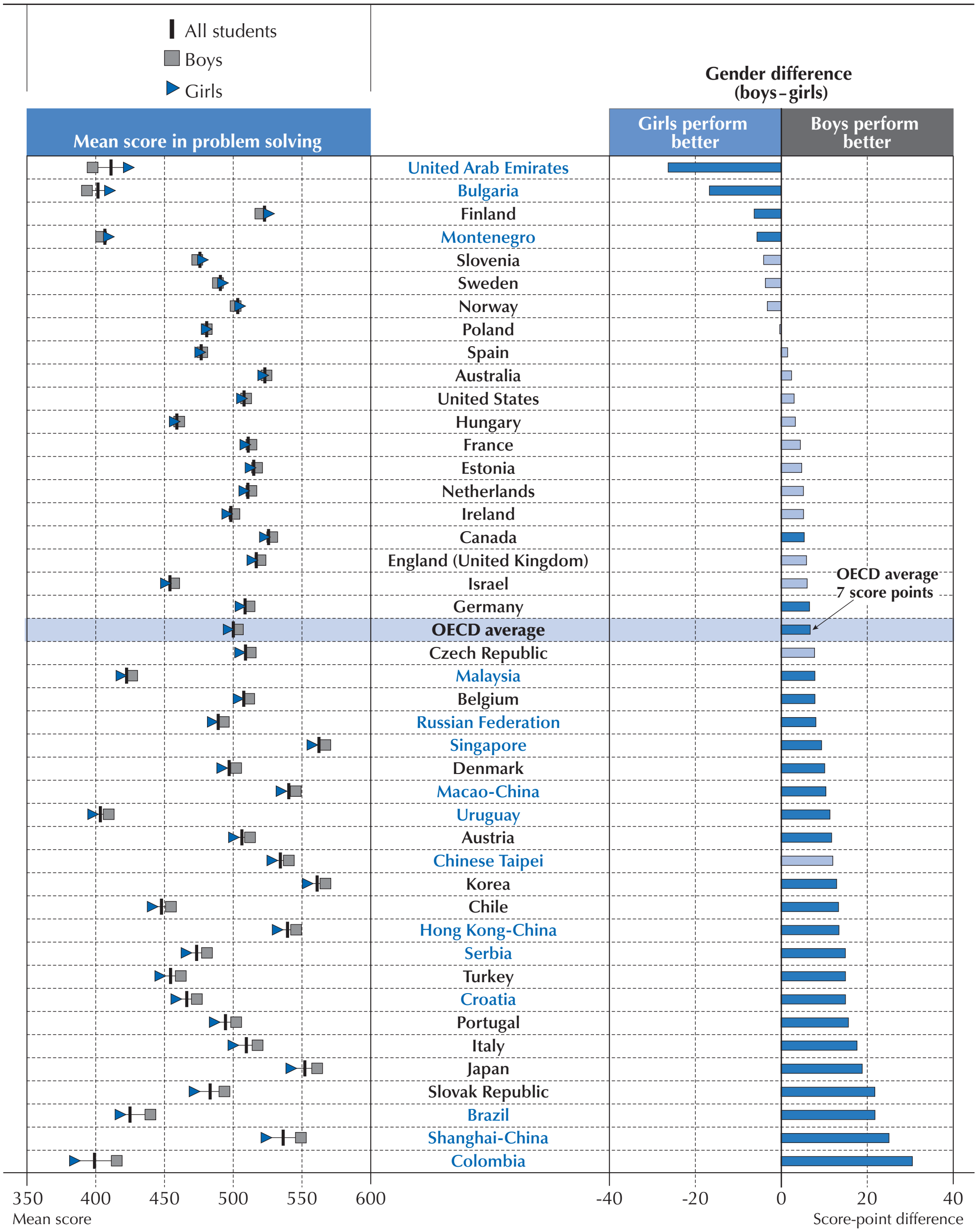
When students are required to employ mathematics concepts, facts, procedures and reasoning to solve a problem, gender differences are much narrower. On average across OECD countries, boys still outperform girls on the *employing* subscale, but by a much smaller margin than on the *formulating* subscale: 9 points compared to 16 points. Gender differences are even narrower when students are asked to carry out a calculation, substitute values into a formula, solve an equation, or apply their knowledge of the conventions of graphing to extract data or present information mathematically. In only one OECD country, Iceland, do girls outperform boys in the *employing* subscale (by 7 points); among partner countries and economies, girls outperform boys on the *employing* subscale in six countries: Jordan, Latvia, Malaysia, Qatar, Singapore and Thailand (Table 1.10b).

Gender differences in favour of boys are also smaller when students are required to interpret, apply and evaluate mathematics outcomes. In interpreting mathematics outcomes, students need to make links between the outcomes and the situation from which they arose. For example, in a problem requiring a careful interpretation of some graphical data, students would have to make connections among the objects or relationships depicted in the graph. The answer to the question might involve interpreting those objects or relationships. On average across OECD countries, boys score 9 points higher than girls in this subscale (Table 1.10c).

Results from PISA 2006 show even larger variations in the relative strengths and weaknesses of boys and girls in performing science-related tasks. Girls tend to outperform boys (by an average of 17 score points, across OECD countries) on tasks where they are required to identify scientific issues, but boys outperform girls in tasks that require them to apply knowledge of science in a given situation, to describe or interpret phenomena scientifically and predict changes, and to identify appropriate scientific descriptions, explanations and predictions.

■ Figure 3.18 ■

Gender differences in problem-solving performance



Note: Statistically significant gender differences are marked in a darker tone.
Countries and economies are ranked in ascending order of the score-point difference (boys – girls).
Source: OECD, PISA 2012 Database, Table 3.11a.

On average across OECD countries, boys outperform girls by 15 score points in these tasks; in Chile, boys outperform girls by 34 score points. The gender difference in score is larger than 20 points in the Czech Republic, Denmark, Germany, Hong Kong-China, Hungary, Luxembourg, the Slovak Republic and the United Kingdom (Tables 1.11a and 1.11b).

By contrast, performance differences between boys and girls are small or non-existent when students are required to interpret scientific evidence, and make and communicate conclusions, identify the assumptions, evidence and reasoning behind conclusions, or reflect on the social implications of science and technological developments (Table 1.11c).

In 2012, PISA conducted a computer-based problem-solving assessment. Problem solving here refers to "students' capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen" (OECD, 2014). Given the advances in understanding the cognitive processes involved in problem solving, and the possibility of using computer-based simulated scenarios, the assessment highlights so-called "interactive" problems.

Figure 3.18 shows that boys score seven points higher than girls in problem solving, on average across OECD countries (Table 3.11a), and that the variation observed among boys is larger than the variation observed among girls (100 points vs. 91 points). In more than half of the countries and economies that participated in the problem-solving assessment, boys outperformed girls, on average. The largest advantages in favour of boys (more than 20 score points) were observed in Brazil, Colombia, Shanghai-China and the Slovak Republic. Only in Bulgaria, Finland, Montenegro and the United Arab Emirates did girls outperform boys, on average. In 16 countries/economies, the difference in performance between boys and girls was not statistically significant.

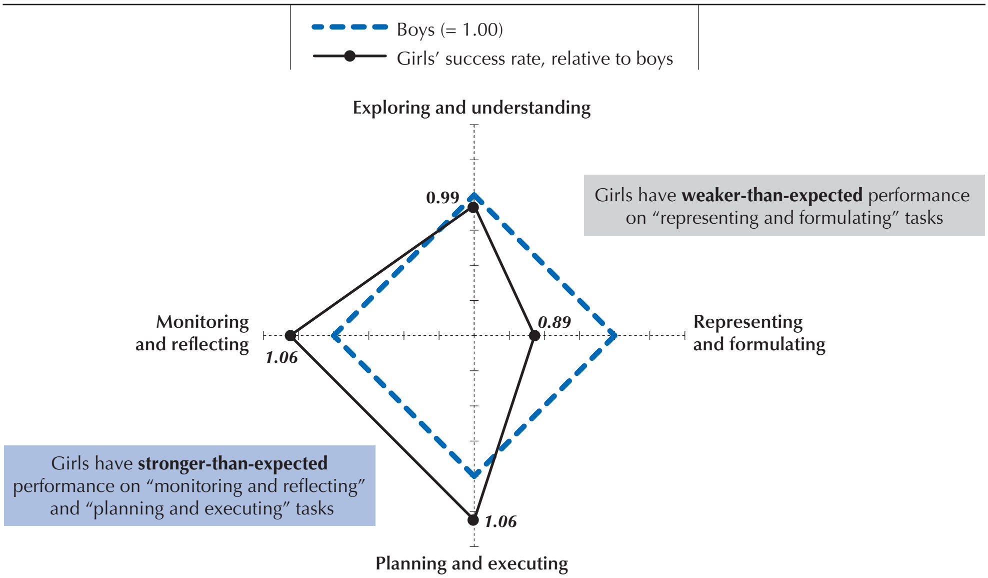
Performance differences between boys and girls vary across the problem-solving assessment, depending on the type of task involved. Boys generally outperform girls on cognitive tasks that require a greater amount of abstract information processing (Halpern and LaMay, 2000). They tend to outperform girls in their ability to transform a visual-spatial image in working memory, and generate and manipulate the information in a mental representation. In the PISA assessment of problem solving, this ability is particularly important for success on *representing and formulating* tasks. Boys' and girls' performance across problem-solving processes differs significantly in 27 of the 43 countries and economies that participated in the assessment. In all but three of these countries/economies, girls scored below their expected level of performance, particularly on items measuring *representing and formulating* processes (Table 3.11c).

In Korea, girls score lower than boys on the problem-solving assessment as a whole. An analysis by families of tasks shows that girls' performance is much weaker than boys' on tasks that measure *exploring and understanding* and *representing and formulating* processes, but is close to boys' performance (and thus stronger than expected) on tasks that measure *planning and executing* and *monitoring and reflecting* ability. As a result of its students' – particularly boys' – strong performance in tasks that measure knowledge acquisition, Korea is a high performer in problem solving.

■ Figure 3.19 ■

Girls' strengths and weaknesses, by problem-solving process

Relative likelihood of success in favour of girls, after accounting for overall performance differences on the test



Notes: Gender differences that are statistically significant are marked in italic.
This figure shows that girls' success rate on items measuring the process of "representing and formulating" is only 0.89 time as large as that of boys, after accounting for overall performance differences on the test and on average across OECD countries.
Source: OECD, PISA 2012 Database, Table 3.11c.

Hong Kong-China and Macao-China show similar patterns: boys outperform girls in problem solving, and particularly in knowledge-acquisition tasks, but not in tasks that measure how well they use the knowledge they have acquired. By contrast, in many European countries, including those with above-average performance in problem solving, such as France, Germany, Italy and the Netherlands, boys and girls perform similarly across the various problem-solving processes (Table 3.11c).

Note regarding Israel

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

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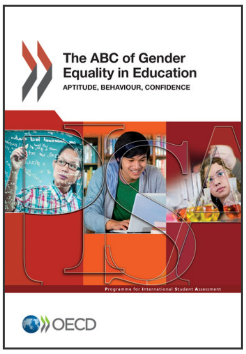

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