4

Opportunity to Learn and Students' Attitudes Towards Mathematics

This chapter explores the relationship between opportunity to learn and students' attitudes towards mathematics, including their interest in mathematics, mathematics self-concept and anxiety towards mathematics. Teaching practices that have an impact on students' self-concept towards mathematics, peer effects and parents' influence on their child's attitudes towards mathematics are also examined.

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.

"I don't expect, and I don't want, all children to find mathematics an engrossing study, or one that they want to devote themselves to either in school or in their lives. Only a few will find mathematics seductive enough to sustain a long-term engagement. But I would hope that all children could experience at a few moments in their careers...the power and excitement of mathematics...so that at the end of their formal education they at least know what it is like and whether it is an activity that has a place in their future."
– David Wheeler (1975, quoted in Cross, 2004)

Positive feelings towards mathematics are closely linked to the ability to solve problems. In fact, it is highly unlikely that mathematical literacy can be acquired and put into practice by someone who does not have some degree of self-confidence, curiosity, interest in and desire to practice and understand mathematics (OECD, 2010; OECD, 2013b).

If not everyone is born to become a mathematician, everyone needs to be able to reason mathematically. Without the correct mindset, a primary school student who has had few opportunities to play with numbers at home might struggle to understand the meaning of arithmetic operations; without arithmetic skills, this same student will have a hard time making sense of algebra. Stimulating positive emotions during mathematics lessons is key to helping students of all ages understand the reasoning behind mathematics, encouraging them to appreciate the value of mathematics, and allowing them to decide whether mathematics should have a central place in their future studies and careers.

What the data tell us

- On average across OECD countries in 2012, 38% of students reported that they study mathematics because they enjoy it and 53% of students reported that they are interested in the mathematics they do at school. More girls (65%) than boys (54%) reported that they often worry about mathematics classes, and disadvantaged students were more likely than advantaged students to believe they are just not good at mathematics.
- Exposure to more complex mathematics concepts, as measured by the *index of familiarity with mathematics*, is associated with lower self-concept and higher anxiety among students in the bottom quarter of mathematics performance, and with higher self-concept/lower anxiety among students in the top quarter of mathematics performance, on average across OECD countries.
- Having hard-working friends can increase mathematics self-concept, but students can develop lower beliefs in their own ability when they compare themselves to higher-achieving peers.
- On average across OECD countries, high-performing students whose parents do not like mathematics are 73% more likely to feel helpless when they face a mathematics problem than high-performing children of parents who like mathematics.
- Students whose mathematics teachers differentiate tasks according to students' abilities and who encourage students to work in small groups have higher mathematics self-concept than students whose teachers do not engage in these practices.

What these results mean for policy

- Mathematics curricula, and the teachers who follow them, should strike a balance between making the material more challenging and aiming to bolster students' – especially low-performing students' – confidence and reduce their anxiety towards mathematics.
- School leaders and teachers should make a careful use of competition and rankings within the classroom, because students' mathematics self-concept is strongly influenced by how their familiarity with mathematics compares with that of their peers.
- Parents should be made aware of their role in transmitting mathematics anxiety to their children and should help motivate them.
- Specific communication training can help teachers to provide more effective feedback to the students who are least familiar with mathematics.

Previous PISA analyses have shown that opportunity to learn mathematics (OTL) is positively related not only to students' performance, but also to positive attitudes towards mathematics. For example, students' confidence in solving specific pure and applied mathematics problems is closely linked to their exposure to similar sets of problems in the classroom (OECD, 2013b). This chapter extends these analyses by focusing on the relationship between OTL and three aspects of students' attitudes towards mathematics (see Box 4.1 for the definition and measurement of these constructs):

- students' intrinsic and instrumental motivation to learn mathematics
- students' mathematics self-concept
- students' mathematics anxiety.

Figure 4.1 illustrates this chapter's analysis of the relationship among exposure to mathematics, performance in mathematics and students' attitudes towards mathematics. Opportunities to practice mathematics in class are positively associated with mathematics performance (Chapter 3); through this channel, they also strengthen students' interest in mathematics, support their self-confidence and reduce anxiety towards mathematics. The type and level of difficulty of mathematics tasks can also be directly associated with students' attitudes, although the direction of the relationship is unclear. On the one hand, more exposure to challenging mathematics problems can stimulate the interest and raise the self-concept of students who are well-trained in mathematics reasoning. On the other hand, exposure to complex mathematics problems can increase pressure on students who have gaps in their learning.

This chapter also looks at other mediators of the relationship between OTL and students' attitudes towards mathematics. The characteristics of students' peers, parents' attitudes towards mathematics, and the quality of teachers and their teaching practices influence how exposure to mathematics in class affects students' drive, self-beliefs and anxiety.

Box 4.1. Students' attitudes towards mathematics analysed in this chapter

The Student Questionnaire that was part of the PISA 2012 assessment included 67 questions that allowed for the construction of ten indices about students' attitudes towards mathematics. This chapter analyses the following indices and indicators:

1) Students' intrinsic and instrumental motivation to learn mathematics

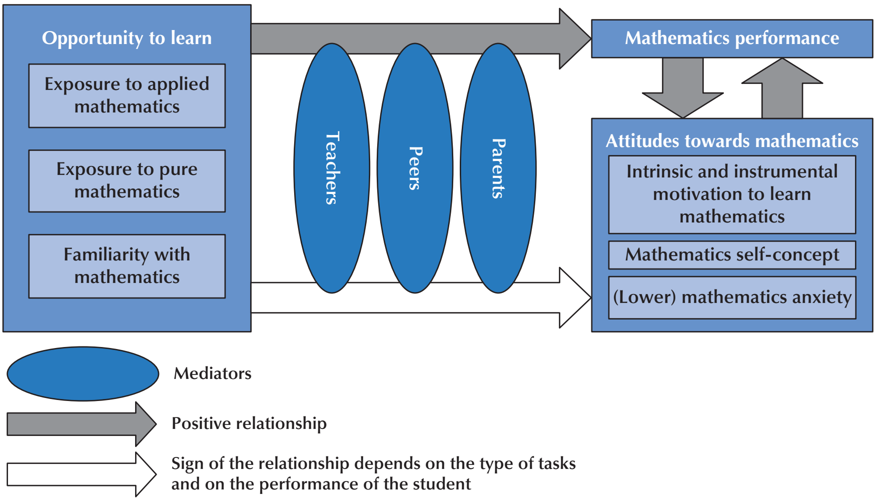
- Intrinsic motivation to learn mathematics (or mathematics interest) measures students' drive to perform an activity purely for the joy gained from the activity itself. The *index of mathematics interest* is based on the degree to which students "strongly agree", "agree", "disagree" and "strongly disagree" with the statements: a) I enjoy reading about mathematics; b) I look forward to my mathematics lessons; c) I do mathematics because I enjoy it; d) I am interested in the things I learn in mathematics.
- Instrumental motivation to learn mathematics refers to students' drive to learn mathematics because they perceive it to be useful to their future studies and careers. The *index of instrumental motivation to learn mathematics* is based on the degree to which students "strongly agree", "agree", "disagree" and "strongly disagree" with the statements: a) Making an effort in mathematics is worth it because it will help me in the work that I want to do later on; b) Learning mathematics is worthwhile for me because it will improve my career; c) Mathematics is an important subject for me because I need it for what I want to study later on; d) I will learn many things in mathematics that will help me get a job.

2) Mathematics self-concept measures students' beliefs in their own mathematics abilities. The *index of mathematics self-concept* is based on the degree to which students "strongly agree", "agree", "disagree" and "strongly disagree" with the statements: a) I am just not good at mathematics; b) I get good grades in mathematics; c) I learn mathematics quickly; d) I have always believed that mathematics is one of my best subjects; e) In my mathematics class, I understand even the most difficult work.

3) Mathematics anxiety measures the feelings of helplessness and stress that students can have when faced with a mathematics problem. The *index of mathematics anxiety* is based on the degree to which students "strongly agree", "agree", "disagree" and "strongly disagree" with the statements: a) I often worry that it will be difficult for me in mathematics classes; b) I get very tense when I have to do mathematics homework; c) I get very nervous doing mathematics problems; d) I feel helpless when doing a mathematics problem; e) I worry that I will get poor marks in mathematics.

Responses to all items were coded so that higher values correspond to a higher level of the construct. All indices were scaled so to have an OECD mean of zero and an OECD standard deviation of one.

■ Figure 4.1 ■
Direct and indirect relationship between opportunity to learn and attitudes towards mathematics



HOW STUDENTS' MOTIVATION AND SELF-BELIEFS VARY ACROSS COUNTRIES AND SUBGROUPS OF STUDENTS

All countries and economies are trying to find ways to spark students' interest in mathematics so that they are motivated to learn. Figure 4.2 shows that, on average across OECD countries in 2012, only 38% of students reported that they study mathematics because they enjoy it; in Austria, only 24% of students reported that they enjoy studying mathematics. By contrast, more than 70% of students in Indonesia and Thailand reported that they enjoy studying mathematics.

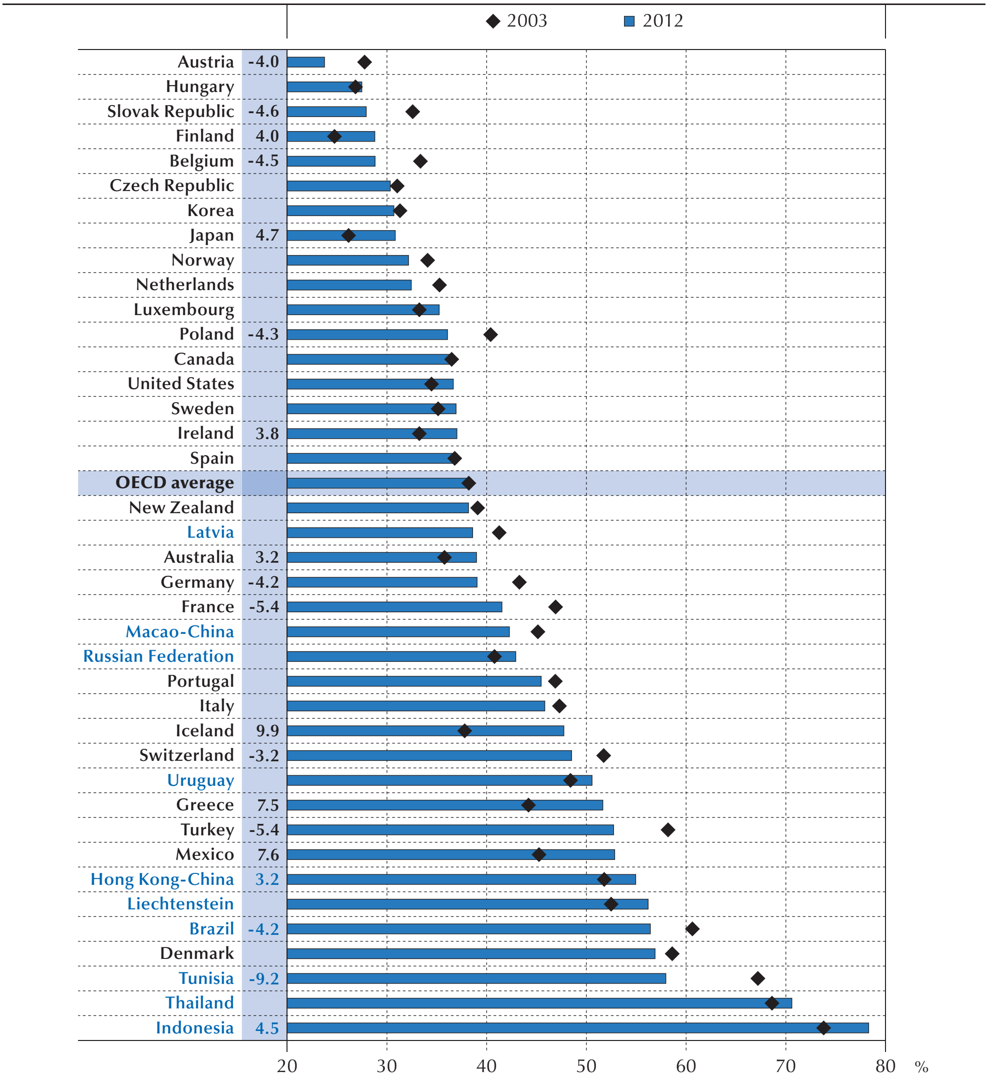
The percentage of students who reported that they enjoy mathematics increased by 4 percentage points or more between 2003 and 2012 in Finland, Greece, Iceland, Indonesia, Japan and Mexico. Students were more likely to report being interested in mathematics than enjoying mathematics when asked about the mathematics they do at school. On average across OECD countries in 2012, 53% of students reported that they are interested in the things they learn in mathematics, the same percentage observed in 2003 (Table 4.1). Between 2003 and 2012, the share of students who reported that they are interested in mathematics grew by 14 percentage points in Greece, but shrunk by 22 percentage points in the Slovak Republic.

How students feel about their mathematics ability (their mathematics self-concept) shapes their behaviour, especially when facing challenging problems (Bandura, 1977). PISA 2012 data show that, on average across OECD countries, 43% of students reported that they agree or strongly agree that they are not good at mathematics; 59% reported that they get good grades in mathematics; 37% reported that they understand even the most difficult work; 52% reported that they learn mathematics quickly; and 38% reported to have always believed that mathematics is one of their best subjects (Table 4.5a). These responses vary markedly across countries and

■ Figure 4.2 ■

Change between 2003 and 2012 in the percentage of students who enjoy mathematics

Percentage of students who reported that they "agree" or "strongly agree" with the statement "I do mathematics because I enjoy it"



Notes: Only countries and economies with comparable data from PISA 2003 and PISA 2012 are shown. The OECD average only accounts for countries that participated in both PISA 2003 and PISA 2012 assessments.

Only statistically significant differences between 2012 and 2003 are shown next to the country/economy name.

Countries and economies are ranked in ascending order of the percentage of students in 2012 who agreed with the statement "I do mathematics because I enjoy it".

Source: OECD, PISA 2012 Database, Table 4.1.

StatLink http://dx.doi.org/10.1787/888933377468

economies. Over 60% of students in Albania, Argentina, Indonesia, Chinese Taipei and Thailand reported that they feel they are not good at mathematics, while these negative perceptions were shared by less than 30% of students in Denmark, Israel and Viet Nam.

Particular groups of students are more likely to develop negative beliefs about their mathematics capacities. Figure 4.3 shows that, in 2012, socio-economically disadvantaged students were much more likely than advantaged students to report that they are not good at mathematics. The socio-economic gap in this measure of mathematics self-concept is larger than 25 percentage points in Bulgaria, France, Greece, Liechtenstein, Portugal and Tunisia. The lower self-confidence in academic ability among disadvantaged students is clearly related to their poorer performance at school. But the concentration within a school of students with a history of negative experiences with mathematics can generate "contagion effects" that reinforce the negative relationship between economic disadvantage and self-concept.

Students who hold negative views about their academic abilities are more likely to suffer from mathematics anxiety. Feelings of anxiety can begin as early as elementary school, and are often prompted by social cues conveying the message that mathematics should be feared (Beilock and Willingham, 2014). The consequences of mathematics anxiety are mild to severe: from minor frustration to overwhelming physical reactions, such as pain (Ashcraft and Moore, 2009). Individuals with high mathematics anxiety perform worse because their worry over-rides their cognitive resources (Maloney and Beilock, 2012).

PISA data show clearly that mathematics anxiety is not limited to a minority of individuals nor to one country. Across OECD countries, around 59% of students often worry that it will be difficult for them in mathematics classes. Girls are more likely to report mathematics anxiety than are boys: on average across OECD countries in 2012, 65% of girls and 54% of boys reported feeling worried about their mathematics classes (Figure 4.4). In Denmark, Finland and Liechtenstein, the difference in the percentage of girls and boys who are anxious towards mathematics is larger than 20 percentage points.

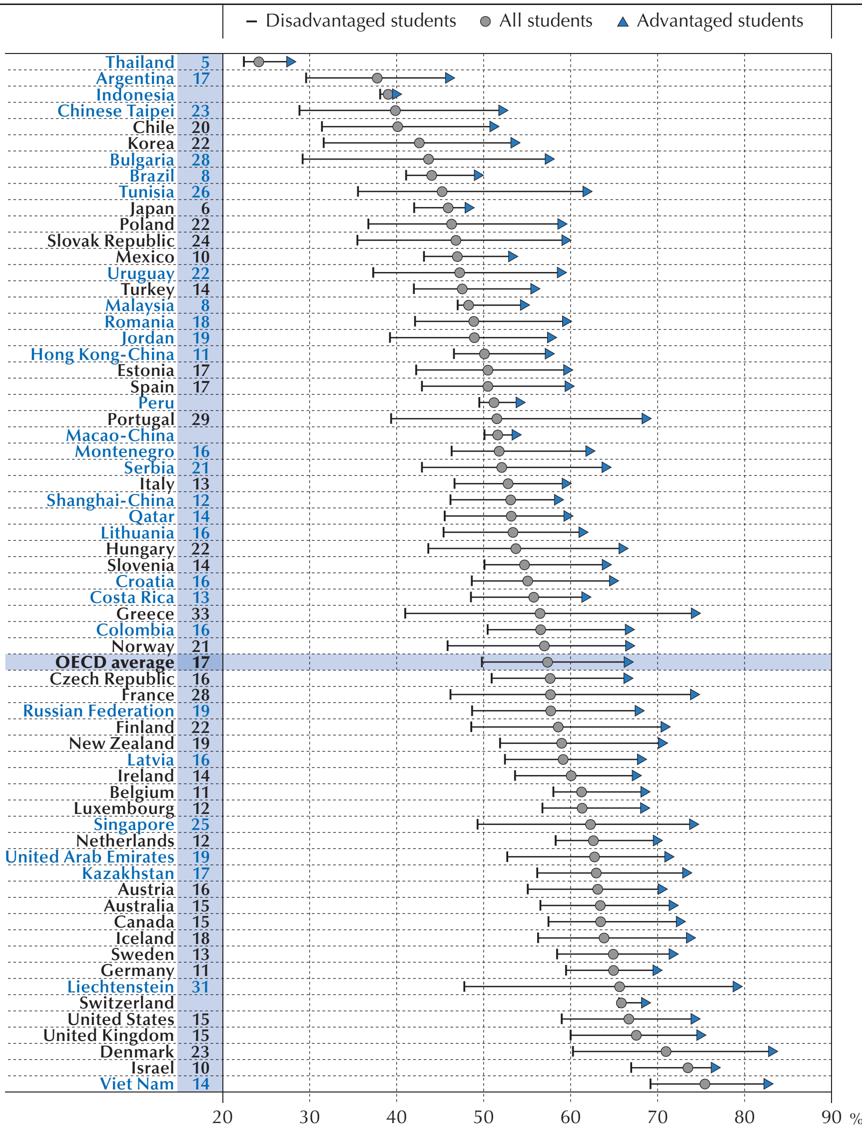
The fear of making mistakes often disrupts performance among gifted girls who "choke under pressure" (OECD, 2015a). The mathematics anxiety experienced by many girls and women has multiple roots. Lower expectations for girls and/or stereotypical thinking that labels mathematics as a more "masculine" subject contribute to mathematics anxiety. Indeed, they might be the greatest obstacles for talented girls and women to overcome on the way to high mathematics achievement (Lavy and Sand, 2015).

The importance of attitudes, beliefs and feelings about mathematics goes beyond the immediate learning context. Students' education pathways and careers might depend on the confidence they have in their abilities to solve mathematics tasks (Hackett and Betz, 1995). In 2012, girls and socio-economically disadvantaged students were less likely than the average student to report that they intended to take additional mathematics courses after the end of compulsory schooling (Figure 4.5).

■ Figure 4.3 ■

Mathematics self-concept, by students' socio-economic status

Percentage of students who reported that they "disagree" or "strongly disagree" with the statement "I am just not good at mathematics"



Notes: Disadvantaged students are defined as those students in the bottom quarter of the *PISA index of economic, social and cultural status* (ESCS). Advantaged students are students in the top quarter of ESCS.

Only statistically significant percentage-point differences between advantaged and disadvantaged students are shown next to the country/economy name.

Countries and economies are ranked in ascending order of the percentage of all students who disagreed with the statement "I'm just not good at mathematics".

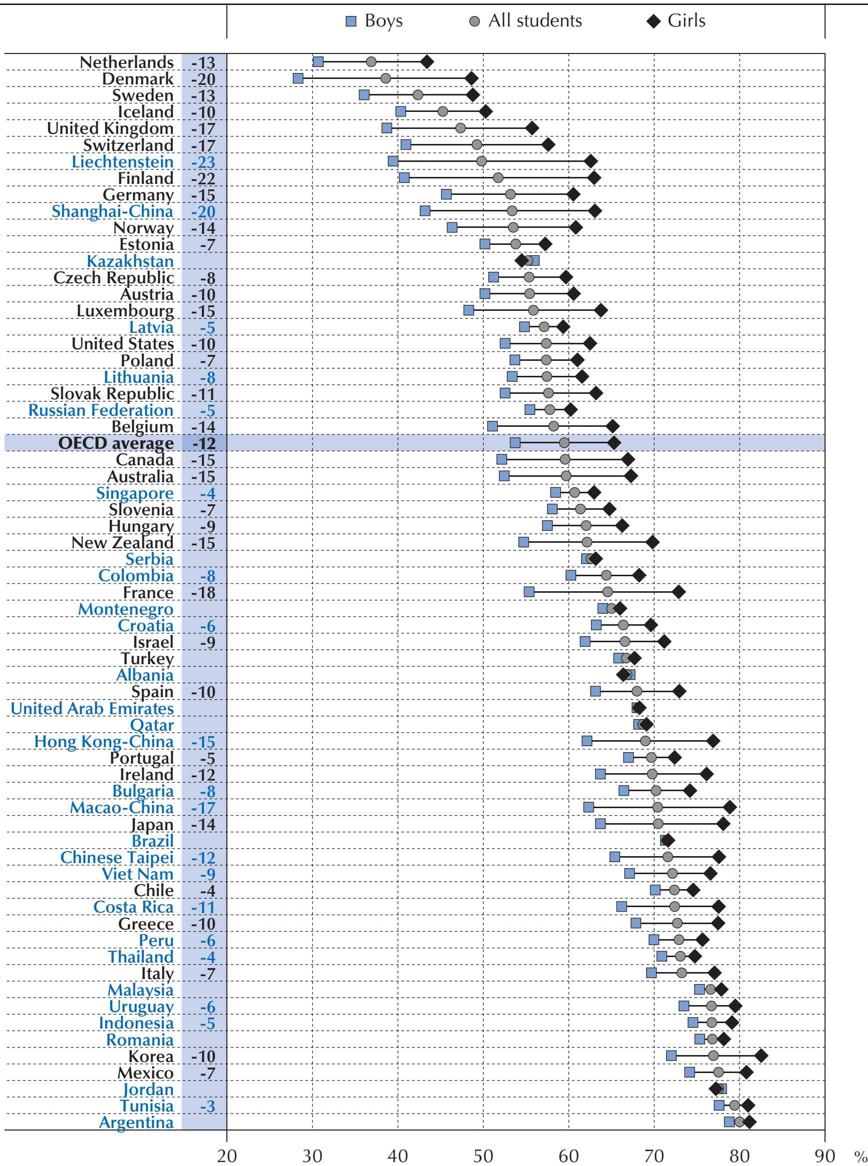
Source: OECD, PISA 2012 Database, Table 4.2.

StatLink http://dx.doi.org/10.1787/888933377470

■ Figure 4.4 ■

Mathematics anxiety, by gender

Percentage of students who reported that they "agree" or "strongly agree" with the statement "I often worry that it will be difficult for me in mathematics classes"



Note: Only statistically significant percentage-point differences between boys and girls are shown next to the country/economy name.

Countries and economies are ranked in ascending order of the percentage of all students who agreed with the statement "I often worry that it will be difficult for me in mathematics classes".

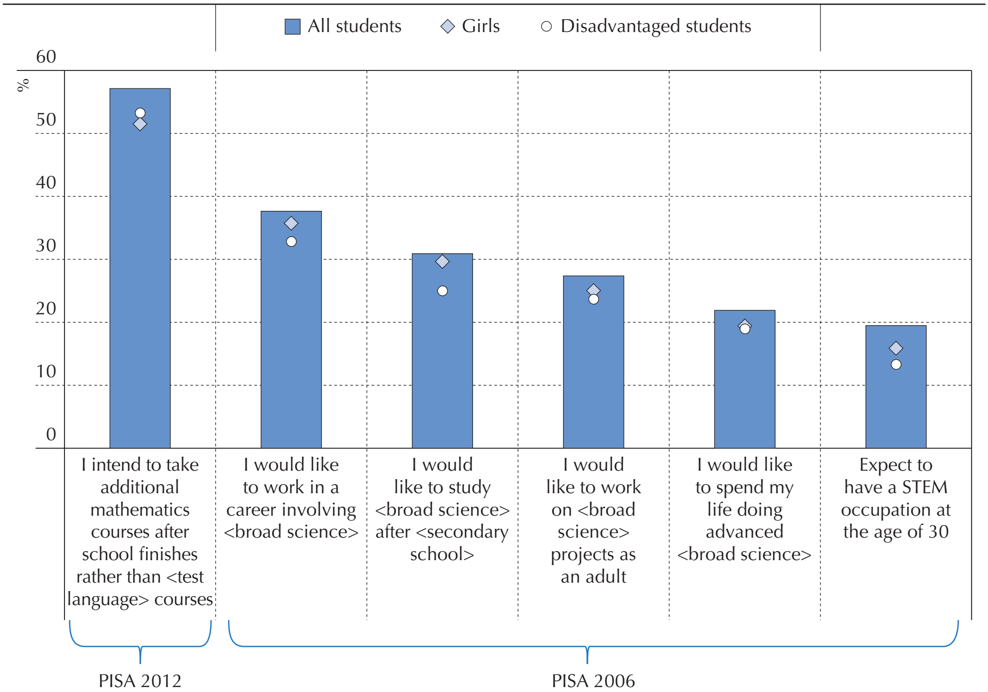
Source: OECD, PISA 2012 Database, Table 4.3.

StatLink http://dx.doi.org/10.1787/888933377487

■ Figure 4.5 ■

Students' intentions, motivation and expected careers in STEM fields, by gender and socio-economic status

Percentage of students who reported that they "agree" or "strongly agree" with the following statements, OECD average



Notes: Disadvantaged students are defined as those students in the bottom quarter of the *PISA index of economic, social and cultural status* (ESCS).
STEM refers to science, technology, engineering and mathematics.
Source: OECD, PISA 2006 and 2012 Databases,Tables 4.4a, b and c.
StatLink *http://dx.doi.org/10.1787/888933377493*

Data on career expectations in PISA 2006 also show that the students more at risk of developing negative attitudes towards mathematics at school – namely girls and disadvantaged students – are also less likely to expect to pursue a scientific career. For example, on average across OECD countries, 19% of students expected to work as a STEM (science, technology, engineering and mathematics) professional (Table 4.4c). Only 13% of disadvantaged students expected to work in one of these fields. These students might back away from the race to mathematics-intensive jobs at the starting line. Similarly, persistent gender-biased expectations about mathematics ability perpetuate the under-representation of women in science and engineering professions (OECD, 2015a).

RELATIONSHIPS BETWEEN OPPORTUNITY TO LEARN AND ATTITUDES TOWARDS MATHEMATICS

Exposure to pure mathematics, familiarity with mathematics and students' attitudes towards mathematics

Exposure to relatively complex mathematics topics may increase the self-concept of students who are relatively well-prepared and ready to be challenged, but it may undermine the self-confidence of students who do not feel up to the task. Recognising the role of attitudes in mathematics performance, some countries and economies explicitly include activities to help students develop positive attitudes towards mathematics in their mathematics curricula (see Box 4.2).

Figure 4.6 looks at how exposure to pure mathematics tasks (linear and quadratic equations) is associated with different measures of mathematics self-concept. On average across OECD countries, students who are more exposed to pure mathematics (by one additional unit on the *index of exposure to pure mathematics*) are over 30% more likely to disagree that they are just

Box 4.2. Developing positive mathematics attitudes as a curriculum objective

Acknowledging the relationship between attitudes towards mathematics and exposure to mathematics, a number of countries and economies have included the development of positive attitudes towards mathematics as one of the goals of their mathematics curricula. For instance, the new **Australian** mathematics curriculum "encourages teachers to help students become *self-motivated, confident* learners [italics ours]" (ACARA, 2016).

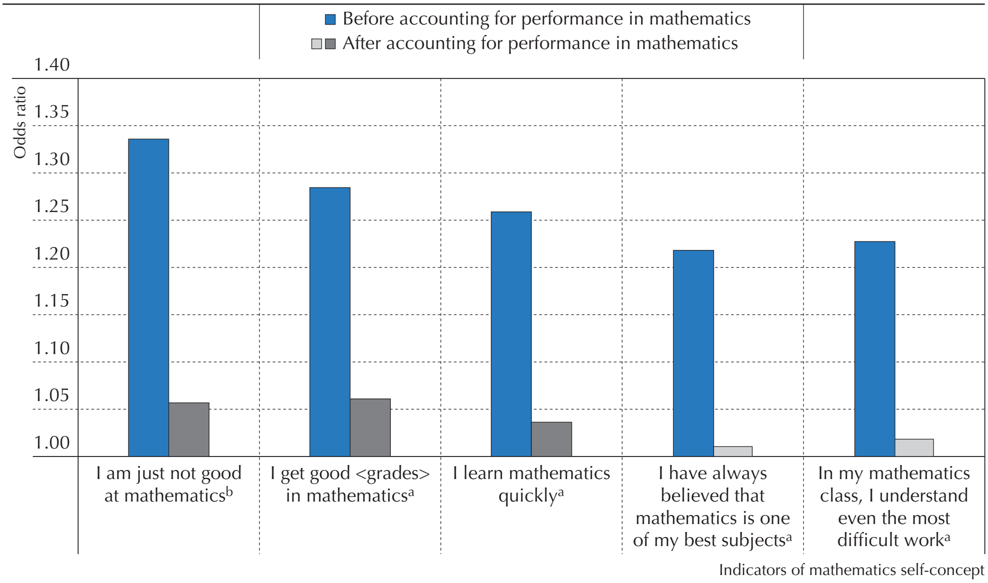
The 2007 and 2011 revisions of the mathematics curriculum in **Korea** introduced a number of new objectives, including the need to develop positive attitudes towards mathematics among students. This idea stemmed from the recognition that previous Korean curricula had fostered the cognitive aspects of mathematics teaching, while attitudes towards mathematics were considered as secondary, albeit instrumental, for developing students' cognitive abilities. Results from the Trends in International Mathematics and Science Study (TIMSS) and PISA confirmed this, as they showed that Korean students consistently displayed high performance in mathematics and problem solving, but had low interest and self-confidence in mathematics (Li and Lappan, 2014). As a part of the 2011 revision of the mathematics curriculum, some content was eliminated or rearranged to significantly reduce students' study load, creating some time for creative and self-directed activities to foster interest in and motivation to learn mathematics (Lew et al., 2012).

Attitudes towards mathematics are one of the five key elements of the mathematics framework that is at the heart of **Singapore**'s mathematics curriculum (Ministry of Education of Singapore, 2012). The framework considers that mathematics education should enable students to develop positive attitudes towards mathematics, including beliefs about the usefulness of mathematics, interest and enjoyment in learning mathematics, confidence in using mathematics and perseverance in solving problems. Similarly, one of the goals of the mathematics curriculum in lower secondary schools in **Hong Kong-China** is to develop positive attitudes towards mathematics (Mullis et al., 2012).

■ Figure 4.6 ■

Exposure to pure mathematics and students' self-concept

Change in the likelihood of students reporting to "agree"/"strongly agree" (a) or "disagree"/"strongly disagree" (b) with the following statements on mathematics self-concept associated with a one-unit increase in the index of exposure to pure mathematics



How to read the chart: An odds ratio of 1.26 corresponding to the statement "I learn mathematics quickly" means that a student who is one standard deviation more exposed to pure mathematics is 26% more likely to agree or strongly agree that he/she learns mathematics quickly compared with a student who is less exposed to pure mathematics.

Notes: The *index of exposure to pure mathematics* measures student-reported experience with mathematics tasks at school requiring knowledge of algebra (linear and quadratic equations).

Statistically significant odds ratios are marked in a darker tone. All values before accounting for performance in mathematics are statistically significant.

Source: OECD, PISA 2012 Database, Table 4.5b.

StatLink *http://dx.doi.org/10.1787/888933377507*

not good at mathematics and they are more than 20% more likely to agree that they get good grades 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 work, compared to students who are less exposed to pure mathematics.

However, once students' mathematics performance is taken into account, the relationship between exposure to mathematics tasks, such as equations, and self-concept becomes weaker. Students of similar ability who are more exposed to pure mathematics are 6% more likely to disagree that they are not good at mathematics, 6% more likely to agree that they get good grades in mathematics, 4% more likely to agree that they learn mathematics quickly and just as likely to agree with the other statements as students who are less exposed (Figure 4.6). After accounting for performance in mathematics, exposure to pure mathematics is not associated with any of the statements about mathematics self-concept in almost half of the countries and economies (Table 4.5b).

This finding suggests that mathematics performance explains the positive relationship between exposure to mathematics and mathematics self-beliefs (see Figure 4.1). High-performing students may be more likely to be exposed to pure mathematics and to express positive feelings towards mathematics. After accounting for mathematics ability, an increase in exposure to pure mathematics corresponds to an increase in mathematics self-concept by more than 0.2 units (equivalent to 20% of a standard deviation for the OECD average) in Kazakhstan, Jordan and Tunisia, but it corresponds to a decrease in mathematics self-concept in Belgium, Denmark, Macao-China, the Netherlands and Switzerland (Table 4.6).

The strong mediating role of mathematics performance is even more apparent when looking at the relationship between self-concept and the *index of familiarity with mathematics*. Figure 4.7 shows that, on average across OECD countries, a one-unit increase in the *index of familiarity with mathematics* corresponds to an increase in the *index of mathematics self-concept* by 10% of a standard deviation before taking mathematics performance into account; but it corresponds to a decrease in that index, by 10% of a standard deviation, when comparing students of similar ability. In Austria, Germany and Liechtenstein, a one-unit increase in the *index of familiarity with mathematics* corresponds to a decrease in the *index of mathematics self-concept* by more than 20% of a standard deviation, after taking mathematics performance into account. As the *index of familiarity with mathematics* is measured on relatively difficult concepts for 15-year-old students, like vectors, complex numbers and congruent figures, it appears that, in most countries, exposure to advanced topics often challenges students' beliefs in their own mathematics abilities.

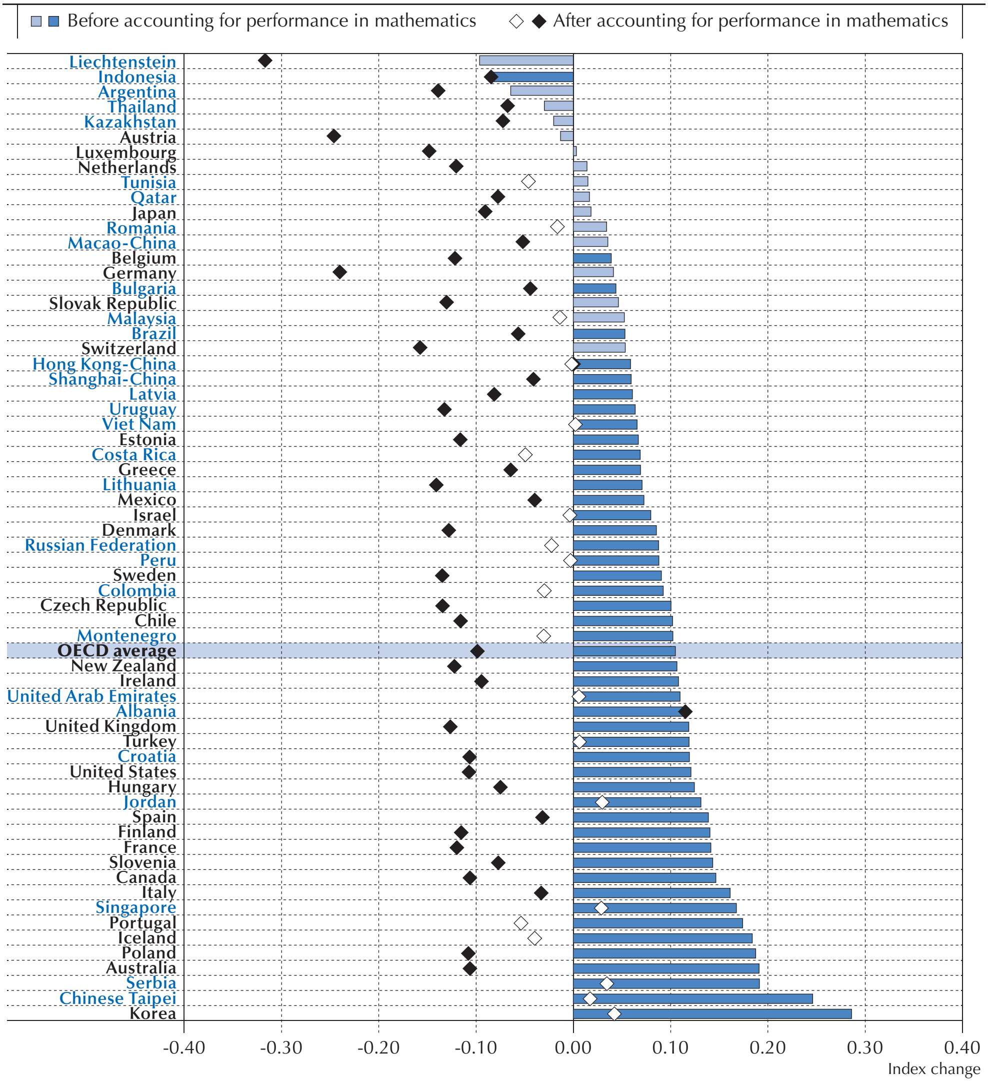
Exposure to relatively formal mathematics, as measured by the *index of exposure to pure mathematics* may also be associated with more anxiety towards mathematics among students who are not sufficiently prepared to learn. On average across OECD countries, students who are more exposed to pure mathematics are 14% more likely to say that they worry that they will get poor grades in mathematics, 8% more likely to worry that it will be difficult for them in mathematics classes, and 4% more likely to report that they get very nervous doing mathematics problems (but 2% less likely to report that they get very tense when they have to do mathematics homework), compared with students of similar mathematics ability who are less exposed to these tasks (Table 4.8b).

Moreover, Figure 4.8 shows that, on average across OECD countries, greater exposure to complex concepts, as measured by the *index of familiarity with mathematics*, is associated with higher anxiety among students in the bottom quarter of the mathematics performance distribution and with lower mathematics anxiety among students in the top quarter of the distribution. The increase in mathematics anxiety among low-performing students associated with a one-unit increase in the *index of familiarity with mathematics* is larger than 10% of a standard deviation in Australia, Austria, Canada, the Czech Republic, France and Chinese Taipei. A similar increase in familiarity with mathematics is associated with a decrease in anxiety by more than 10% of a standard deviation among high-performing students in Albania, Colombia, Hong Kong-China, Hungary, Malaysia, Peru, Romania, Serbia and Slovenia. Similar patterns are found when looking at the effect of exposure to pure mathematics on anxiety along the performance distribution. In France, both high-performing and low-performing students reported

■ Figure 4.7 ■

Relationship between familiarity with mathematics and students' self-concept

Change in the index of mathematics self-concept *associated with a one-unit increase in the* index of familiarity with mathematics



Notes: The *index of mathematics self-concept* is based on the degree to which students agree with the statements: I'm just not good in mathematics; I get good grades in mathematics; I learn mathematics quickly; I have always believed that mathematics is one of my best subjects and In my mathematics class, I understand even the most difficult work.

The *index of familiarity with mathematics* is based on students' responses to 13 items measuring students' self-reported familiarity with mathematics concepts (such as exponential function, divisor, quadratic function, etc.).

Statistically significant values are marked in a darker tone.

Countries and economies are ranked in ascending order of the relationship between familiarity with mathematics and students' self-concept before accounting for performance in mathematics.

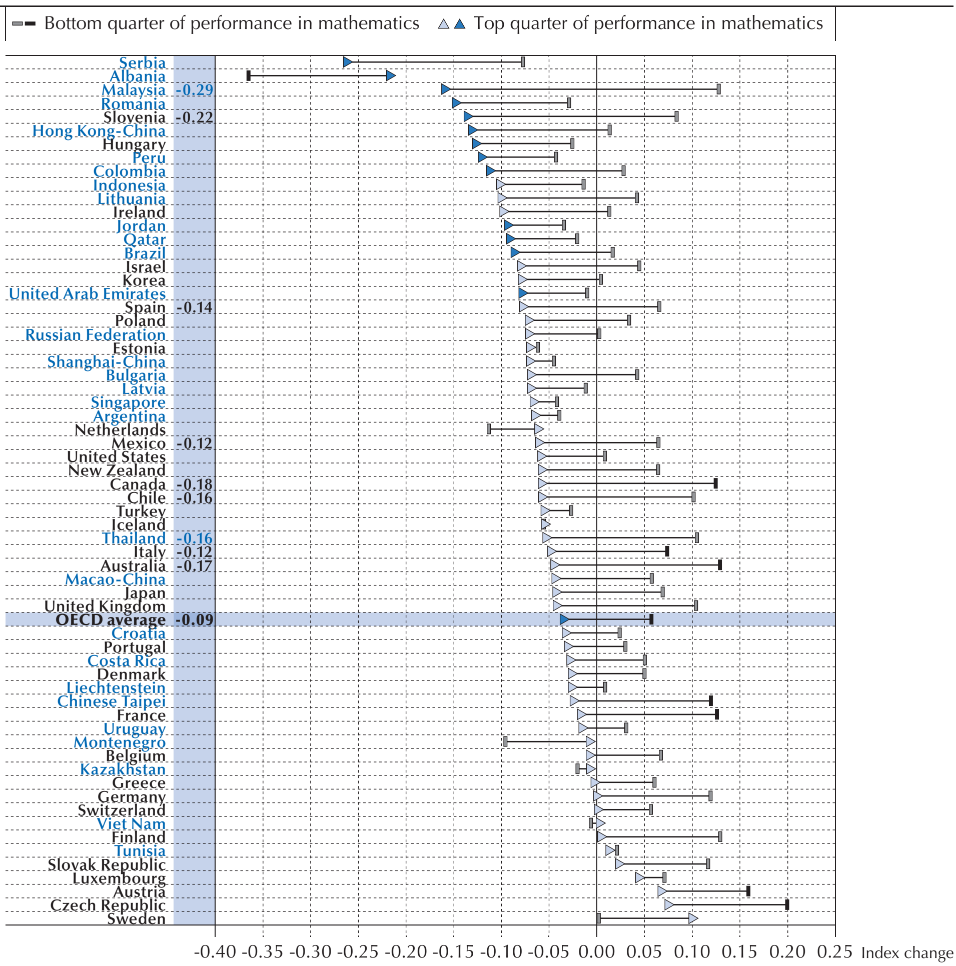
Source: OECD, PISA 2012 Database, Table 4.6.

StatLink http://dx.doi.org/10.1787/888933377511

■ Figure 4.8 ■

Familiarity with mathematics and mathematics anxiety, by students' performance in mathematics

Change in the index of mathematics anxiety *associated with a one-unit increase in the* index of familiarity with mathematics, *among students in the top and bottom 25% of the mathematics performance distribution*



Notes: The *index of mathematics anxiety* is based on the degree to which students agree with the statements: I often worry that it will be difficult for me in mathematics classes; I get very tense when I have to do mathematics homework; I get very nervous doing mathematics problems; I feel helpless when doing a mathematics problem; and I worry that I will get poor marks in mathematics.

The *index of familiarity with mathematics* is based on students' responses to 13 items measuring students' self-reported familiarity with mathematics concepts (such as exponential functions, divisor, quadratic function, etc.).

Statistically significant differences between students in the top and bottom quarter of performance in mathematics are shown next to the country/economy name.

Only countries and economies with available data are shown.

Countries and economies are ranked in ascending order of the index change for the students in the top quarter of performance in mathematics.

Source: OECD, PISA 2012 Database, Table 4.10b.

StatLink *http://dx.doi.org/10.1787/888933377524*

greater anxiety when they are more exposed to pure mathematics tasks, such as solving linear and quadratic equations (Table 4.10b).

All in all, the analysis of the relationship between opportunities to learn mathematics, mathematics performance and attitudes towards mathematics suggests that exposure to challenging mathematics content can help improve performance (Chapter 3). At the same time, such exposure could backfire if students, particularly low-achieving students, develop negative attitudes and self-beliefs towards mathematics as a result. Chapter 5 discusses the implications of these results for policy, and suggests that mathematics curricula, and the teachers who follow those curricula, should strike a balance between making mathematics lessons challenging and aiming to bolster students' self-confidence and reduce their anxiety towards mathematics.

Exposure to applied mathematics and students' attitudes towards mathematics

By contrast, exposing students to problems that ask them to apply mathematics in a real context seems to be a way to expand their opportunity to learn while, at the same time, reinforcing their self-beliefs. On average across OECD countries, students who reported that they are frequently exposed to contextualised mathematics problems (such as interpreting a trend in a chart; see Chapter 1) tend to have higher values on the *index of mathematics self-concept* by 10% of a standard deviation compared with students who are less frequently exposed to these problems, after accounting for their mathematics performance (Figure 4.9). The increase in self-concept associated with being frequently exposed to contextualised mathematics problems is larger than 25% of a standard deviation in Austria, Bulgaria, Croatia, Luxembourg and Montenegro (Table 4.7a).

Students' practice with relatively simple applied mathematics tasks, as measured by the *index of exposure to applied mathematics*, seems to have a different effect on mathematics anxiety than exposure to more abstract content, once students' performance is taken into account. On average across OECD countries, more frequent exposure to the relatively difficult mathematics concepts captured by the *index of familiarity with mathematics* and the *index of exposure to pure mathematics* increases students' anxiety, after accounting for mathematics performance (Table 4.9). By contrast, the association between more frequent exposure to applied mathematics and mathematics anxiety is not statistically significant, after accounting for mathematics performance.

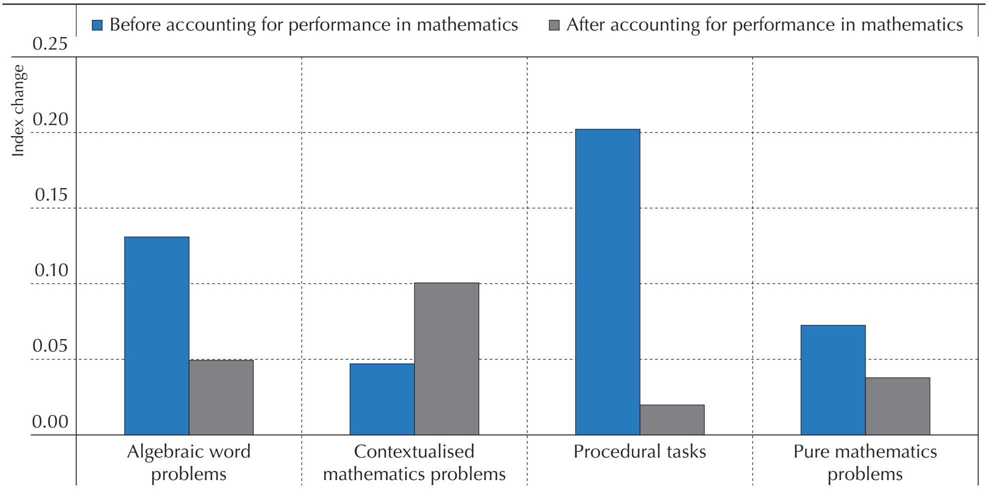
Mathematics assessments and anxiety

Anxiety can be related not only to exposure to mathematics during lessons but also to mathematics assessments (Reys et al., 2014). Mathematics anxiety causes greater deterioration in performance when mathematics knowledge and practice is tested under timed, high-stakes conditions (Ashcraft and Moore, 2009). On average across OECD countries, students tend to show higher values on the *index of mathematics anxiety* when they are more frequently exposed to pure mathematics problems during school tests (Table 4.7d; see Chapter 1 for examples of the various tasks).

■ Figure 4.9 ■

Relationship between exposure to mathematics tasks during mathematics lessons and students' self-concept

Change in the index of mathematics self-concept *associated with frequent exposure to mathematics tasks during during lessons, OECD average*



Notes: The *index of mathematics self-concept* is based on the degree to which students agree with the statements: I'm just not good in mathematics; I get good grades in mathematics; I learn mathematics quickly; I have always believed that mathematics is one of my best subjects and In my mathematics class, I understand even the most difficult work.
See Chapter 1 for examples of the various tasks.
All values are statistically significant.
Source: OECD, PISA 2012 Database, Table 4.7a.
StatLink *http://dx.doi.org/10.1787/888933377533*

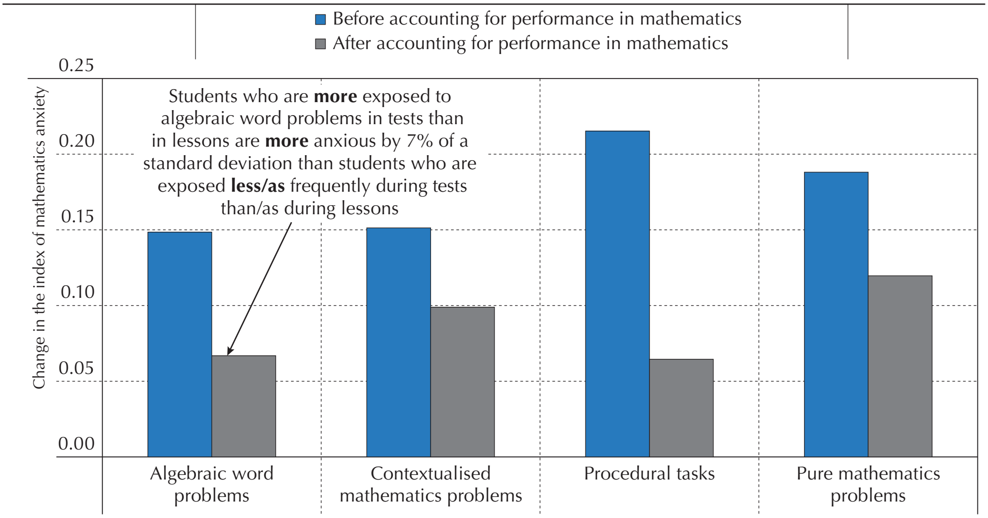
Students are more likely to feel anxious if they are assessed on a topic that they have not practiced very often during classroom lessons. About 10% of students, on average across OECD countries, reported that they are more frequently exposed to algebraic word problems in tests than in lessons; 17% of students in the United Kingdom reported that they are more frequently exposed to pure mathematic problems in tests than they are in mathematics classes (Table 4.7e).

Figure 4.10 shows that, on average across OECD countries, students who are exposed more frequently to pure and contextualised mathematics tasks in tests than in lessons feel more anxious by at least 10% of a standard deviation than students who are exposed less or equally frequently during tests than during lessons, after accounting for their mathematics performance. Students in Austria who are exposed more frequently to pure and contextualised mathematics tasks in tests than in lessons feel more anxious by more than 30% of a standard deviation than students who are exposed less or equally frequently during tests than during lessons, after accounting for their mathematics performance (Table 4.7f). More frequent use of contextualised problems in tests than in lessons is associated with a larger increase in mathematics anxiety than more frequent use of procedural tasks in tests than in lessons, possibly because contextualised problems are more unpredictable than procedural problems.

■ Figure 4.10 ■

Mathematics anxiety and the mismatch between what is taught and what is tested

Change in the index of mathematics anxiety *associated with more frequent exposure to mathematics tasks during tests than during lessons, OECD average*



How to read the chart: This figure compares students who are exposed more frequently to mathematics tasks in tests than in lessons to students who are exposed to mathematics tasks less/as frequently in tests than/as in lessons.
Notes: The *index of mathematics anxiety* is based on the degree to which students agree with the statements: I often worry that it will be difficult for me in mathematics classes; I get very tense when I have to do mathematics homework; I get very nervous doing mathematics problems; I feel helpless when doing a mathematics problem; and I worry that I will get poor marks in mathematics.
All values are statistically significant.
Source: OECD, PISA 2012 Database, Table 4.7f.
StatLink *http://dx.doi.org/10.1787/888933377548*

MEDIATING FACTORS BETWEEN EXPOSURE TO MATHEMATICS AND ATTITUDES TOWARDS MATHEMATICS

Students learn mathematics in the context of their classroom and families, and the relationship between exposure to mathematics and self-beliefs is likely to be mediated by students' peers, parents and teachers. This section considers how peers, parents and teachers can influence the relationship between exposure to mathematics and students' intrinsic and instrumental motivation to learn mathematics, as well as their self-concept and anxiety towards mathematics.

The benefits and possible shortcomings of hard-working and well-prepared peers

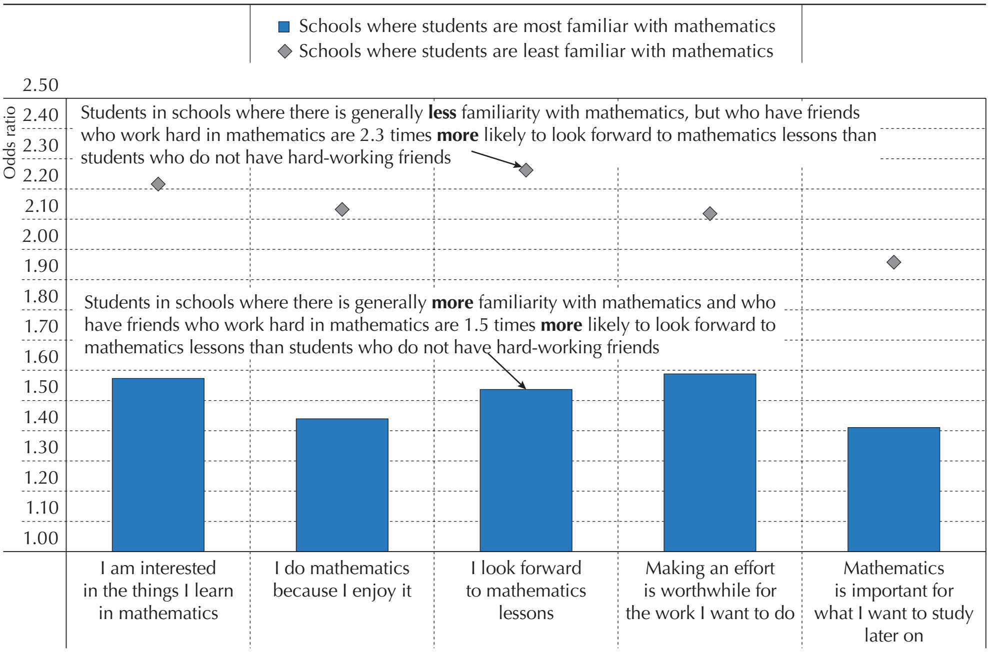
Peer quality and behaviour are important determinants of student outcomes (Sacerdote, 2001; Jencks and Mayer, 1990). Peer effects are central to many important policy issues in education, including the impact of ability tracking between and within schools, "mainstreaming" special education students, and programmes for racial and economic desegregation. The effect of grouping students in classrooms by ability, for example, affects students' achievement not only by influencing the instruction they are exposed to, but also by limiting their classroom interactions to those with only high-achieving peers (for those in higher tracks) or to those with only low-achieving peers (for those in lower tracks [Angrist and Lang, 2004; Cooley, 2007; Fryer and Torelli, 2010]).

The characteristics of students' peers are clearly related to the academic credentials of the schools they attend. PISA 2012 data show that 56% of students in schools where the students' level of familiarity with mathematics is above the country average and 49% of the students in schools where the students' level of familiarity with mathematics is below the country average reported having friends who work hard on mathematics, on average across OECD countries (Table 4.12a). In both types of schools, students of similar ability with hard-working friends have higher intrinsic and instrumental motivation to learn mathematics (Figure 4.11).

■ Figure 4.11 ■

Motivation to learn mathematics and peers' attitudes, by schools' level of familiarity with mathematics

Change in the likelihood of students reporting that they "agree" or "strongly agree" with the following statements on the motivation to learn mathematics associated with having friends who work hard in mathematics, OECD average



How to read the chart: An odds ratio of 2.22 corresponding to the statement "I am interested in the things I learn in mathematics" means that a student who has friends who work hard in mathematics is 2.22 times more likely to agree or strongly agree with the statement than a student who does not have friends who work hard in mathematics.
Notes: Schools with less (more) familiarity with mathematics are defined as those schools where the average familiarity with mathematics is significantly lower (higher) than the country average familiarity with mathematics.
All odds ratios are statistically significant.
Source: OECD, PISA 2012 Database, Table 4.11.
StatLink *http://dx.doi.org/10.1787/888933377553*

This relationship is not causal, as hard-working and motivated students are likely to self-select into groups of hard-working friends. But it is interesting to observe that the positive relationship between a student's interest in mathematics and the attitudes towards mathematics of his or her peers are stronger in the schools that teach relatively less advanced mathematics, even after taking mathematics performance into account. The data thus suggest that students in schools that are not academically challenging would benefit even more than students in academically rigorous schools from having a network of friends who like mathematics. A possible explanation is that students in academically rigorous or socio-economically advantaged schools have more access to other resources (e.g. parental involvement) that are substitutes for peers who are interested in mathematics.

To the extent that attending a school with highly motivated peers creates incentives for students to work on mathematics, disadvantaged students can be expected to benefit from attending advantaged schools. However, desegregation policies that allow disadvantaged students to attend high-achieving schools do not always work as expected. As a result of a background of disadvantage and low achievement, a disadvantaged student attending an advantaged school may suffer from social isolation or even discrimination if he or she is not well-prepared to be among a minority in the school (Montt, 2012). The disadvantaged student may also suffer from an "invidious comparison" with his/her higher-achieving peers, leading to lower self-concept and achievement (Hoxby and Weingarth, 2005).

Figure 4.12 shows that students' mathematics self-concept is associated with the students' relative position in the school. In almost all countries and economies, students who reported less familiarity with mathematics than the average student in the school have lower mathematics self-concept. Particularly in Korea and Chinese Taipei, students who reported a level of familiarity with mathematics below the average student in their school feel like "the small frogs of the pond" (Marsh and Hau, 2003), meaning that their self-concept is undermined by social comparisons with peers who have a greater familiarity with mathematics.

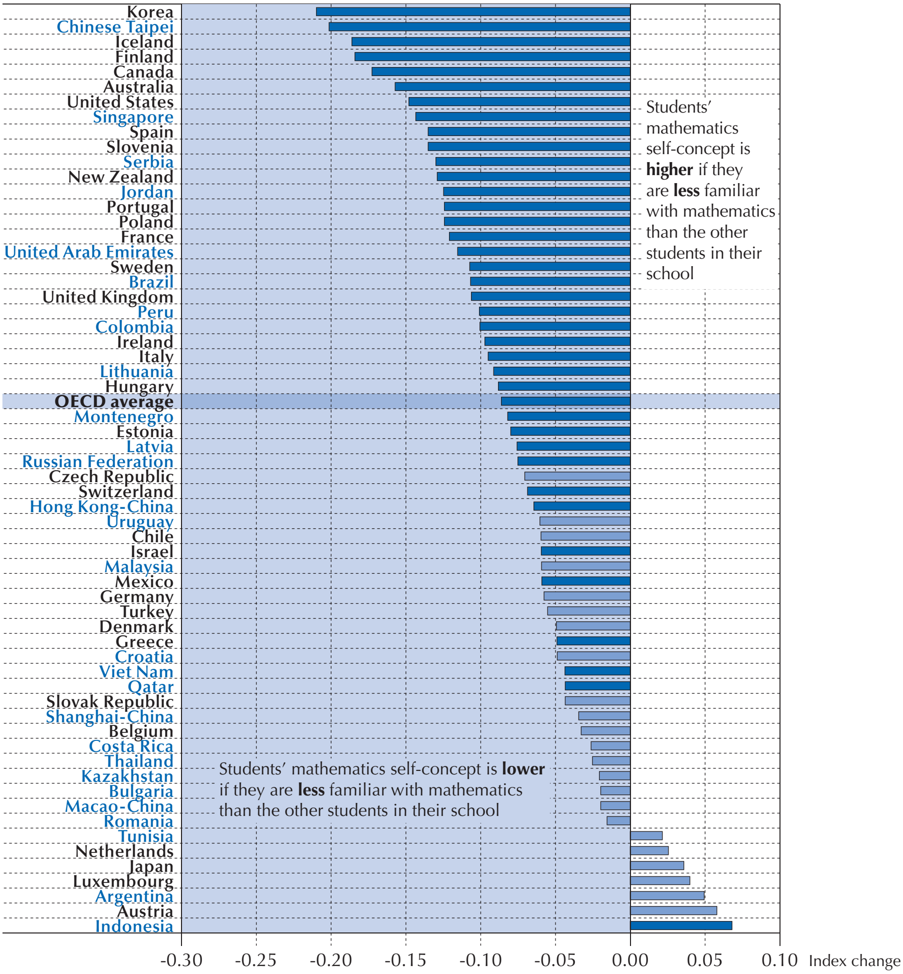
The research on the effects of school composition has often failed to integrate the impact of students' relative social and academic standing on the psychological and competitive atmosphere in the school. This is problematic because this atmosphere affects students' achievement, well-being, beliefs and expectations about their future studies and jobs. The organisation of school systems and teaching practices can have an effect on whether an academically or socio-economically disadvantaged student is pushed ahead through positive "contagion" from his or her higher-achieving peers, or pushed back by humiliating social comparisons.

For example, both positive and negative peer effects tend to be weaker in stratified school systems because these systems institutionalise the norms and information students consider when forming their expectations (Montt, 2012). A closer look at the real-life experiences of poor and minority students in high-achieving schools can help to identify the psychological, pedagogical and instructional challenges of "detracking" and integration across achievement levels (Rosenbaum, 1999).

■ Figure 4.12 ■

Mathematics self-concept and relative familiarity with mathematics compared with schoolmates

Change in the index of self-concept *associated with a one-unit difference between the school's average familiarity and the student's familiarity with mathematics*



Notes: The *index of mathematics self-concept* is based on the degree to which students agree with the statements: I'm just not good in mathematics; I get good grades in mathematics; I learn mathematics quickly; I have always believed that mathematics is one of my best subjects and In my mathematics class, I understand even the most difficult work.

The *index of familiarity with mathematics* is based on students' responses to 13 items measuring students' self-reported familiarity with mathematics concepts (such as exponential functions, divisor, quadratic function, etc.).

The results are based on a multi-level model and account for the gender and socio-economic status of the student (at the student level) and for the percentage of girls, the socio-economic profile of the school and the average level of familiarity with mathematics in the school (at the school level).

Statistically significant values are marked in a darker tone.

Countries and economies are ranked in ascending order of the index change in familiarity with mathematics associated with larger differences between the school's and the student's familiarity.

Source: OECD, PISA 2012 Database, Table 4.12b.

StatLink *http://dx.doi.org/10.1787/888933377566*

Parental involvement and children's mathematics anxiety

Parents are their children's first and longest-serving teachers (Maloney et al., 2015). Many of the basic ideas that support formal mathematics later in life are constructed during the first years of a child's life, through interaction with the adults in their surrounding environment. Over the course of these interactions, parents' attitudes towards mathematics are often passed on to their child. What makes mathematics different from other subjects is that it is considered socially acceptable to say "I am not a maths person" or "I never liked maths". Unlike other weaknesses that are hidden, mathematical illiteracy is flaunted by many people (Paulos, 2011). When a parent does that in front of a child, he or she is suggesting that mathematics is not important or that only some people need to understand mathematics.

PISA data show that parents participate actively in their child's learning. On average across the 11 countries and economies where the PISA Parent Questionnaire was distributed, 81% of parents reported discussing how the child is doing at school at least once a week; 78% of parents reported eating the main meal with their child almost every day; 65% of parents reported spending time just talking to their child at least once a week; 19% of parents reported obtaining mathematics materials for their child at least once a week; and 32% of parents reported discussing with their child how mathematics can be applied to everyday life at least once a week (OECD, 2013b: Table III.6.1a).

On average, these activities are positively associated with students' mathematics performance and with other indicators of students' attitudes towards learning, such as the likelihood of arriving on time for classes (OECD, 2013b). However, research shows that the effects of parental involvement on a child's achievement vary according to parents' behaviour, the child's grade level, and the racial, ethnic and socio-economic background of the family (Robinson and Harris, 2014).

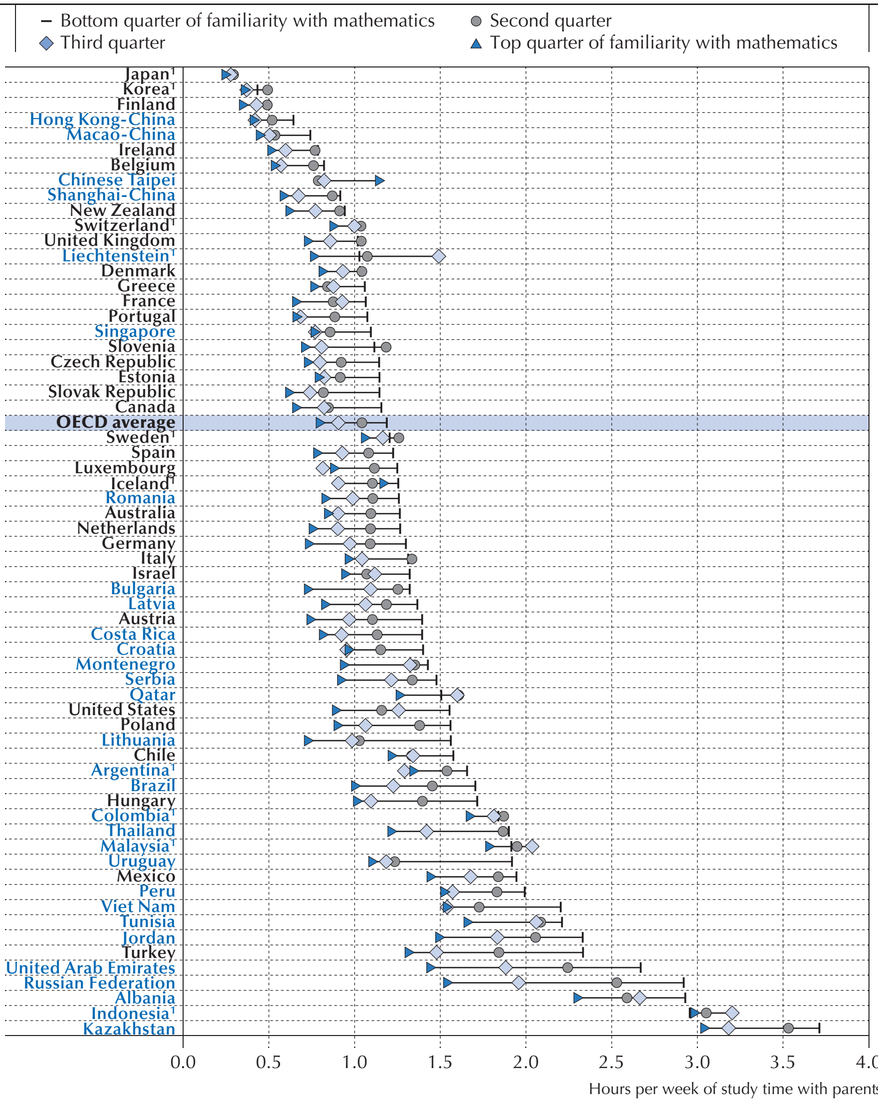
The major vehicle through which parents help their children with school subjects is homework. On average across OECD countries, 44% of 15-year-old students reported spending some time each week studying with a parent (Table 4.13). Studying with parents is much less common in East-Asian countries and economies. Less than 30% of students in Hong Kong-China, Japan, Korea, Macao-China, Shanghai-China, Singapore and Chinese Taipei study with their parents.

Parents are more likely to intervene when their children struggle with mathematics. Figure 4.13 shows that, on average, students in the lower quarter of the *index of familiarity with mathematics* spend 1 hour and 11 minutes studying with their parents, while students in the top quarter spend less than 1 hour.[1] The difference in study time with parents between students who are less familiar with mathematics and students who are more familiar with mathematics is larger than 1 hour per week in the Russian Federation, Turkey and the United Arab Emirates.

■ Figure 4.13 ■

After-school study time with parents, by students' level of familiarity with mathematics

Average number of hours per week that students spend studying with a parent or other family member



1. The difference between students in the top and in the bottom quarters of the *index of familiarity with mathematics* is not statistically significant.

Notes: The *index of familiarity with mathematics* is based on students' responses to 13 items measuring students' self-reported familiarity with mathematics concepts (such as exponential function, divisor, quadratic function, etc.).

Countries and economies are ranked in ascending order of study time for students in the bottom quarter of familiarity with mathematics.

Source: OECD,PISA 2012 Database, Table 4.13.

StatLink http://dx.doi.org/10.1787/888933377572

What happens when a parent who dislikes mathematics, or is anxious about mathematics, tries to help his or her child with homework? Recent research has shown that when parents who are anxious towards mathematics frequently help their children with mathematics homework, their help can backfire, leading to greater mathematics anxiety and less mathematics learning for their children (Maloney et al., 2015). In expressing their own dislike of and confusion about mathematics, these parents may be inadvertently transferring their own attitudes to their children.

Mathematics anxiety is even evident among "smart" students. On average across OECD countries, 13% of the students in the top quarter of the mathematics performance distribution reported feeling helpless when doing mathematics problems (Table 4.14a). This lack of self-confidence is more common among top-performing girls (16%) than among top-performing boys (10%).

Parents who send positive messages about mathematics can help dispel the anxiety that distorts students' perceptions of their problem-solving abilities. Figure 4.14 shows that, on average across OECD countries, high-performing students who reported that their parents do not like mathematics are 73% more likely to feel helpless when they are doing mathematics problems than the high-performing children of parents who like mathematics. High-performing students in Croatia, Finland, Hungary and the Netherlands whose parents dislike mathematics are more than 2.5 times more likely to feel helpless when doing mathematics than high-performing students whose parents like mathematics.

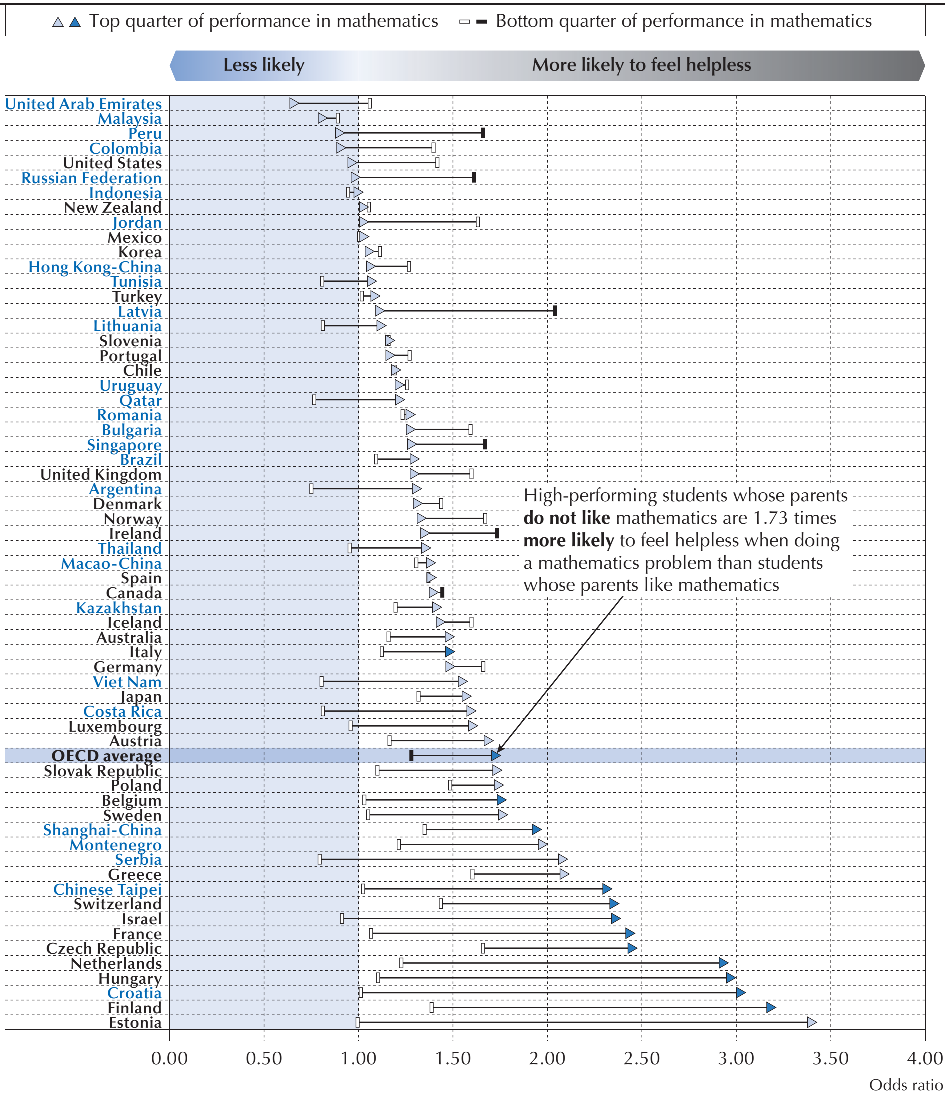
This finding confirms results from experimental research showing that mathematics success can be inherited, not only through genetics but also because children often believe that they cannot do much better than their parents. For example, an experiment examined students' concern about their relative performance when completing a mathematics task on a computer (Jury, Smeding and Darnon, 2015). In the experiment, researchers noted how often students' eyes moved towards an arrow on the screen showing how well they were doing compared with other students. Students whose parents did not complete higher education were more worried about others' performance than students from more-educated families. This concern explained their underperformance: when the arrow was not shown on the screen, there was no performance difference between the two groups of students. Students from less-educated families, or whose parents have a poorer record in mathematics, might thus be more likely to believe in the received wisdom that they cannot succeed, and are more sensitive to signals that might confirm this failure.

One essential ingredient for children's success is for parents to communicate that solving mathematics problems can be a pleasant and rewarding activity. This is a message that all parents should be sending early in their child's lives and that needs to be reinforced over time (Robinson and Harris, 2014).

■ Figure 4.14 ■

Parents' attitudes towards mathematics and students' anxiety, by performance in mathematics

Change in the probability that students feel helpless when doing mathematics problems associated with reporting that their parents do not like mathematics



How to read the chart: An odds ratio of 2 means that students whose parents do not like mathematics are twice as likely as students whose parents like mathematics to feel helpless when doing a mathematics problem.
Notes: The results take into account students' gender and socio-economic status.
Statistically significant odds ratios are marked in a darker tone.
Countries and economies are ranked in ascending order of the odds ratio for students in the top quarter of performance in mathematics.
Source: OECD, PISA 2012 Database, Table 4.14b.
StatLink http://dx.doi.org/10.1787/888933377584

Teachers' practices and attitudes towards mathematics

Teachers' communication about mathematics and students' anxiety

Together with parents, teachers are major role models for students. The way teachers communicate and structure their teaching practices is likely to affect students' attitudes towards mathematics. Traditional practices in mathematics classes, such as imposed authority, public exposure and timed deadlines, may cause great anxiety in many students (Curtain-Phillips, 1999). Consequently, teaching methods that use competition judiciously, communicate clearly, de-emphasise speed tests or drills, and reduce the pressure from major tests and examinations could alleviate students' mathematics anxiety (Beilock and Willingham, 2014; Furner and Berman, 2003; Maloney and Beilock, 2012; Rossnan, 2006).

In particular, communication about learning objectives and feedback on students' performance can be ways of reducing students' mathematics anxiety. A number of teachers' communication strategies, such as telling students what they have to learn, what is expected of them in a test, quiz or assignment, and how well they are doing in mathematics class, are related to less mathematics anxiety among students (Table 4.15).

However, such communication does not work in the same way (or is not expressed in the same way) for all students. Figure 4.15 shows that the communication practices listed above reduce anxiety among students who are more familiar with mathematics; but giving students feedback on their strengths and weaknesses in mathematics, and telling them what they need to do to become better in mathematics actually increase anxiety among students who are less familiar with mathematics. In interpreting the results, one has to keep in mind that this relationship may be mediated by the quality of the teachers: good teachers can provide greater exposure to mathematics content and communicate well with their students at the same time.

Teaching practices that build mathematics self-concept

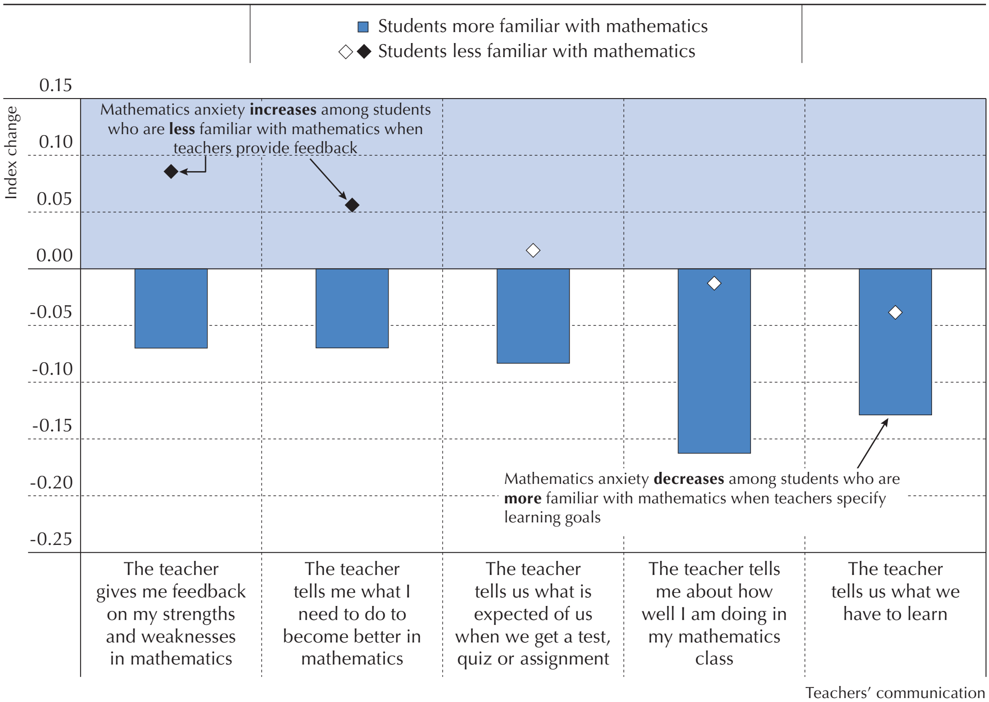
Classroom practices that help students focus their attention and engage in the mathematics task at hand may also help reduce the incidence of poor performance that results from mathematics anxiety and low mathematics self-concept. A number of practices, such as differentiating tasks based on students' abilities, splitting students into small groups, helping students understand, and using cognitive-activation strategies, are associated with higher mathematics self-concept (Table 4.16). While the use of these teaching practices is associated with higher self-concept across students, regardless of how familiar they are with mathematics, the effect is not necessarily of the same magnitude for all students.

The use of teaching practices that differentiate tasks according to students' ability and encourage students to work in small groups is associated with a greater increase in self-concept among students who are less familiar with mathematics than among students who are more familiar with mathematics (Figure 4.16 and Table 4.16). Students who are less familiar with mathematics are likely to feel less competition with peers when they work in small groups and when they receive relatively more individualised teaching (Marsh, 1993; Pajares and Schunk, 2001). Giving students extra help, taking the time to explain the subject until students understand, and using cognitive-activation strategies, such as assigning problems that require students to think for an extended time, seem to benefit all students. Students who are more familiar with mathematics benefit the most from these practices, possibly because students who do more advanced mathematics also tend to be paired with more effective teachers.

■ Figure 4.15 ■

Teaching practices and students' mathematics anxiety, by students' level of familiarity with mathematics

Change in the index of mathematics anxiety *associated with having mathematics teachers who provide feedback or specify learning goals in every or most lessons, OECD average*



Notes: The *index of mathematics anxiety* is based on the degree to which students agree with the statements: I often worry that it will be difficult for me in mathematics classes; I get very tense when I have to do mathematics homework; I get very nervous doing mathematics problems; I feel helpless when doing a mathematics problem; and I worry that I will get poor marks in mathematics.

The *index of familiarity with mathematics* is based on students' responses to 13 items measuring students' self-reported familiarity with mathematics concepts (such as exponential function, divisor, quadratic function, etc.).

Students with less (more) familiarity with mathematics are students in the bottom (top) quarter of the distribution of familiarity. The results take into account students' gender and socio-economic status.

The OECD average for students who are more/less familiar with mathematics is calculated only for countries with a valid index change across both categories and across countries with available data.

Statistically significant values are marked in a darker tone. All values for students who are more familiar with mathematics are statistically significant.

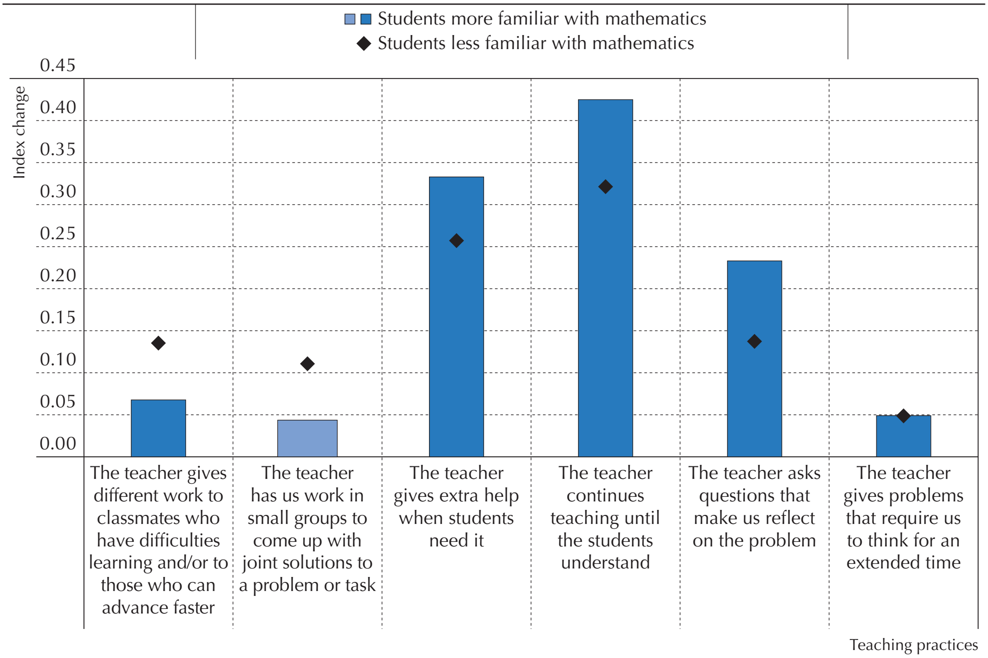
Source: OECD PISA 2012 Database, Table 4.15.

StatLink *http://dx.doi.org/10.1787/888933377594*

■ Figure 4.16 ■

Teaching practices and students' mathematics self-concept, by students' level of familiarity with mathematics

Change in the index of mathematics self-concept *associated with having mathematics teachers who provide feedback or specify learning goals in every or most lessons, OECD average*



Notes: The *index of mathematics self-concept* is based on the degree to which students agree with the statements: I'm just not good in mathematics; I get good grades in mathematics; I learn mathematics quickly; I have always believed that mathematics is one of my best subjects and In my mathematics class, I understand even the most difficult work.
The *index of familiarity with mathematics* is based on students' responses to 13 items measuring students' self-reported familiarity with mathematics concepts (such as exponential function, divisor, quadratic function, etc.).
Students with less (more) familiarity with mathematics are students in the bottom (top) quarter of the distribution of familiarity with mathematics.
The results take into account students' gender and socio-economic status.
The OECD average for students who are more/less familiar with mathematics is calculated only for countries with a valid index change across both categories and across countries with available data.
Statistically significant values are marked in a darker tone. All values for students who are less familiar with mathematics are statistically significant.
Source: OECD PISA 2012 Database, Table 4.16.
StatLink *http://dx.doi.org/10.1787/888933377601*

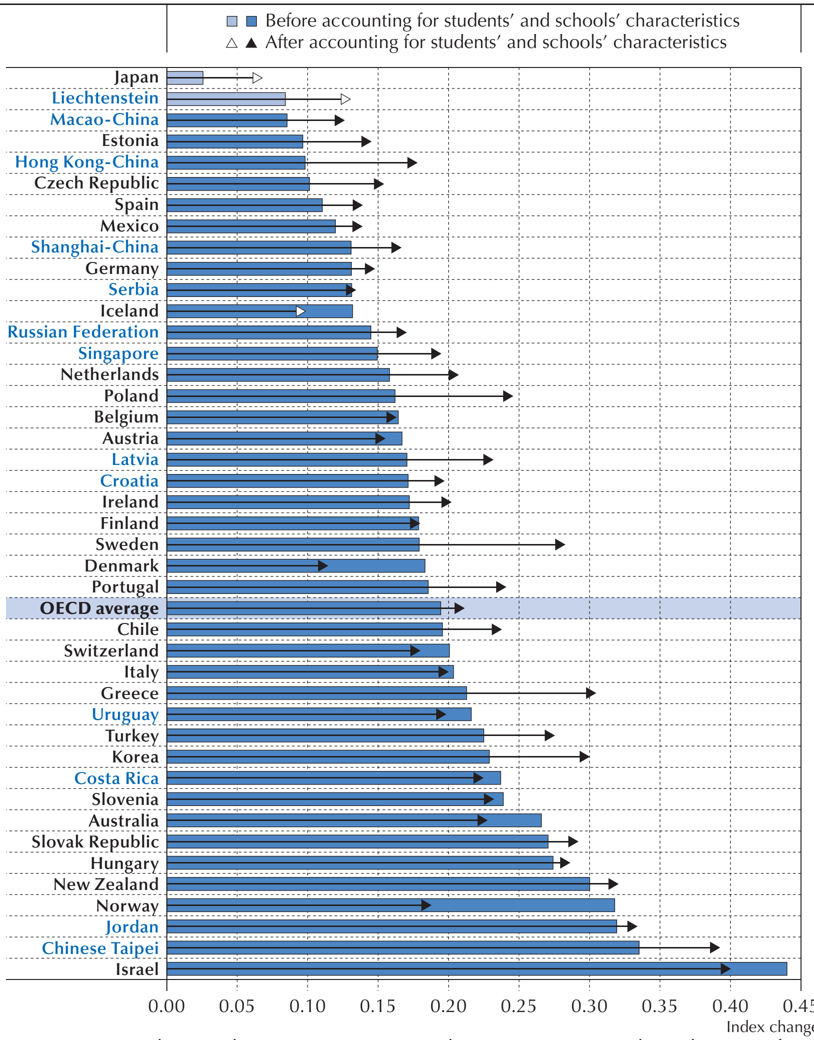
Innovative teaching instruments that foster motivation to learn mathematics

Using innovative teaching instruments can also help to engage students and spark an interest in mathematics. In particular, using technology in teaching mathematics can encourage students to become active participants during class. Figure 4.17 shows that using a computer during mathematics lessons is associated with an increase in the *index of intrinsic motivation for mathematics* (mathematics interest) corresponding to 19% of a standard deviation, on average across OECD countries. Even after taking into account students' and schools' characteristics,

■ Figure 4.17 ■

Students' interest in mathematics and their use of computers in mathematics lessons

Change in the index of intrinsic motivation *for mathematics associated with using a computer in mathematics class*



Notes: Intrinsic motivation to learn mathematics (or interest in mathematics) measures students' drive to perform an activity purely for the joy gained from the activity itself. The *index of intrinsic motivation for mathematics* is based on the degree to which students agree or disagree with the statements: I enjoy reading about mathematics; I look forward to my mathematics lessons; I do mathematics because I enjoy it; I am interested in the things I learn in mathematics.

"Students' and schools' characteristics" include: student's gender, socio-economic status and mathematics performance, and the school's socio-economic profile.

Statistically significant values are marked in a darker tone.

Countries and economies are ranked in ascending order of the change in the index of intrinsic motivation for mathematics *before accounting for students' characteristics.*

Source: OECD, PISA 2012 Database Table 4.17.

StatLink *http://dx.doi.org/10.1787/888933377617*

students' use of a computer in class is related to an increase in interest in mathematics of at least 30% of a standard deviation in Greece, Israel, Jordan, New Zealand and Chinese Taipei.

Dynamic graphical, numerical and visual technological applications (e.g. the interactive whiteboard) can provide new opportunities for teachers and students to interact with, represent and explore mathematics concepts. However, teachers need to be well-trained and practice extensively with these tools if they are to be effective (OECD, 2015b).

The importance of choosing well-framed and engaging problems

Mathematics tasks are central to students' learning because "tasks convey messages about what mathematics is and what doing mathematics entails" (National Council of Teachers of Mathematics, 1991: p. 24). The mathematics problems to which many students are exposed are often nothing more than routine exercises organised to provide practice on a particular mathematics technique that, usually, has just been demonstrated to the student (Schoenfeld,1992). The traditional mathematics class follows a linear structure: a task is used to introduce a technique; the technique is illustrated; more tasks are provided so that the student may practice the illustrated skills. Rather than being engaged in "real" problem solving, students only work on the tasks that have been set before them. This kind of routine, which assigns a passive role to students, might not stimulate interest and engagement.

Solving problems and making up new ones is the essence of mathematics (Boaler, 2015) and is what makes mathematics so intriguing to proficient practitioners. Presenting a problem and developing the skills needed to solve that problem can be more motivational for students than teaching students how to apply a procedure without a context. Teaching through real problems allows students to see a reason for learning a specific topic or concept, and thus become more deeply involved in learning it. Working with open-ended and modelling tasks, in particular, provides students with opportunities not just to apply mathematics but also to learn new mathematics concepts and practice their computational skills (Henningsen and Stein, 1997).

Teachers can more easily stimulate the interest of their students by posing problems that relate conceptual knowledge with a practical application that students find familiar. Research shows that students perform better when they are familiar with the context used to present a particular problem set – for example, when the context refers to an experience they personally lived through (Chiesi, Spilich and Voss, 1979; Alexander and Judy 1988; Alexander, Kulikowich and Schulze, 1994). Using practical applications should thus be encouraged as long as students are helped to transfer what they learn on the tasks to other contexts (see Box 1.3 in Chapter 1).

The structure of PISA assessments allows researchers to investigate how well students do in problems that are contextualised in different ways, as test items are cast in four different contexts: personal, occupational, societal and scientific. Problems classified in the personal context category focus on activities carried out by students, their families and their peers; problems in the occupational context are set in the world of work; problems in the societal context focus on the students' community, whether local, national or global; and problems classified in the scientific category relate to the application of mathematics to the natural world and to issues and topics related to science and technology (OECD, 2013a).

Figure 4.18 shows that socio-economically disadvantaged students perform relatively better on items framed in a personal context than on problems framed in the other contexts. On average across OECD countries, disadvantaged students were 39% less likely than other students to answer correctly test questions framed in a personal context, 45% less likely to answer correctly questions in a societal context, and about 50% less likely to answer correctly questions with an occupational or scientific context, after accounting for other characteristics of the tasks, such as their difficulty. A careful selection of the context of applied problem thus matters. Collaborative efforts involving mathematics researchers, teachers and students should develop and share contextualised tasks that are both challenging and engaging, particularly for those students who have low familiarity with mathematics.

DEVELOPING KNOWLEDGE OF AND ENGAGEMENT WITH MATHEMATICS AT THE SAME TIME

A coherent curriculum paired with well-structured instruction materials is a prerequisite for developing conceptual knowledge of mathematics. In turn, conceptual knowledge is important for mathematics problem solving (Chapter 3). However, simply assigning challenging mathematics tasks to students will not automatically engage them. Students cannot be expected to develop the capacity to think, reason and solve problems mathematically if teachers do not use the kinds of cognitive-activation teaching strategies that have been proven to be the most effective for student learning (Henningsen and Stein, 1997).

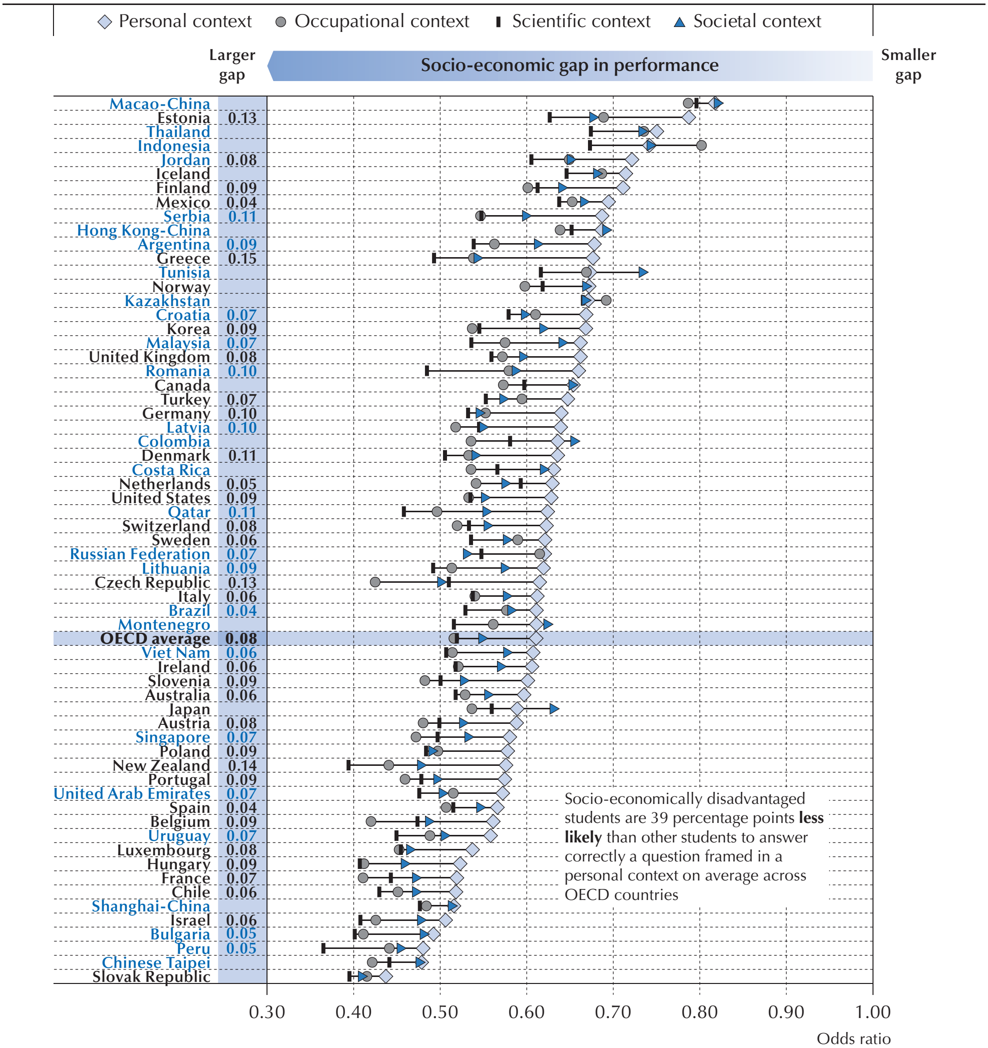
Figure 4.19 shows that students' interest in mathematics can complement exposure to content in developing mathematical literacy. On average across OECD countries, the relationship between exposure to pure mathematics and performance in PISA is stronger – by five score points – among students who are interested in what they study in class than among students who are not interested. In Hungary and Slovenia, the change in performance associated with more exposure to pure mathematics is more than 15 score points greater among students who reported that they are interested in what they learn at school than among students who reported that they are not interested.

Mathematics is more than a static, structured system of facts, procedures and concepts (Henningsen and Stein, 1997); but large numbers of mathematics students only see the facts and do not get a sense of the questions behind the answers (Boaler, 2015). Moreover, many students have problems keeping up with fast-paced mathematics lessons, and thus develop ever-widening gaps in their knowledge and understanding, and lose some self-belief. It is possible, although not easy, to make mathematics concepts more engaging and more finely tuned to the capacities of the weakest students in the class without compromising the integrity of the activity (Houssart, 2004). Everyone involved in mathematics education – teachers, school leaders, teacher educators, researchers, parents, specialist support services, school boards and policy makers, as well as students themselves – has a role to play in changing the way mathematics is taught so that it becomes more intriguing and engaging for all students (Anthony and Walshaw, 2009).

■ Figure 4.18 ■

Performance gap between disadvantaged and other students, by context of task

Change in the probability of answering correctly questions framed in different contexts associated with being in the bottom quarter of socio-economic status



How to read the chart: An odds ratio of 0.61 associated with questions framed in a personal context means that socio-economically disadvantaged students are 39 percentage points ([1-0.61]*100) less likely than other students to answer correctly a problem framed in a personal context.

Notes: Disadvantaged students are defined as those students in the bottom quarter of the *PISA index of economic, social and cultural status* (ESCS).

Odds ratios for all item contexts are statistically significant. Statistically significant differences between odds ratios referring to personal context items and odds ratios for all the other items are shown next to the country/economy name.

Countries and economies are ranked in descending order of the odds ratios for items framed in a personal context.

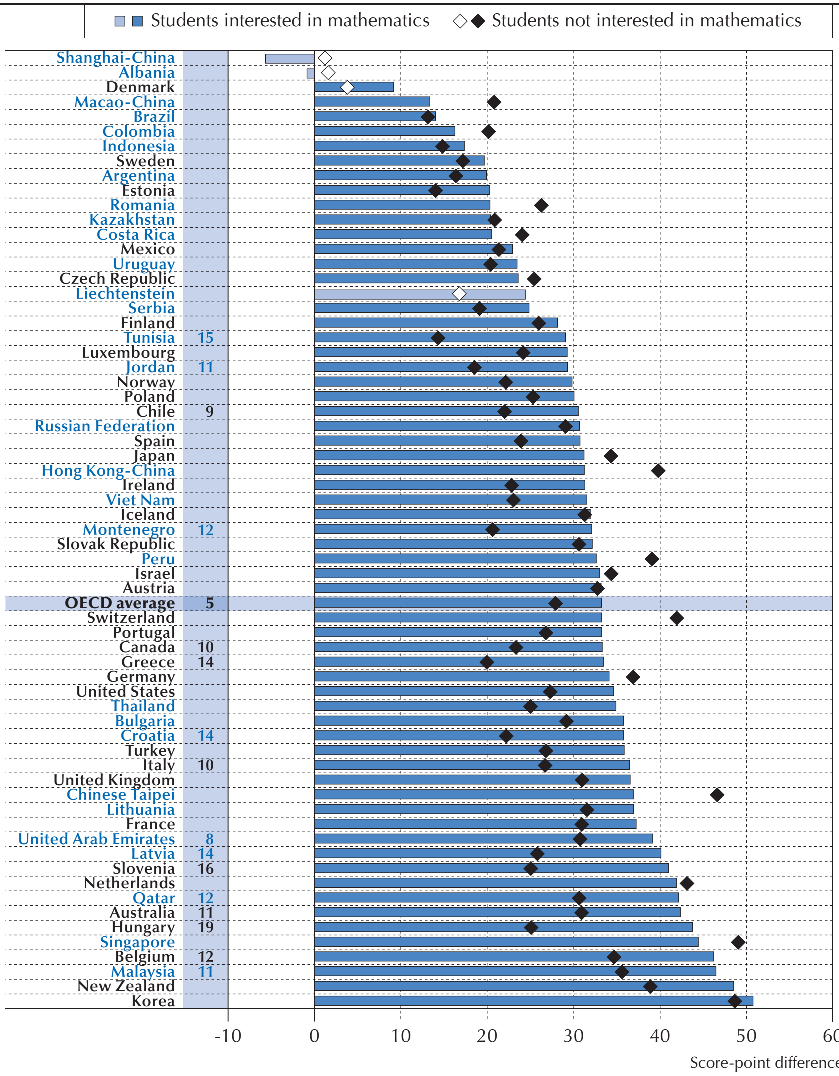
Source: OECD, PISA 2012 Database Table 4.18.

StatLink http://dx.doi.org/10.1787/888933377621

■ Figure 4.19 ■

Relationship between exposure to pure mathematics and mathematics performance, by students' interest in mathematics

Change in mathematics performance associated with a one-unit change in the index of exposure to pure mathematics, *by students' interest in mathematics*



Notes: The *index of exposure to pure mathematics* measures student-reported experience with mathematics tasks at school requiring knowledge of algebra (linear and quadratic equations).
Statistically significant differences between students who are interested and not interested in mathematics are shown next to the country/economy name.
Statistically significant values are marked in a darker tone.
Countries and economies are ranked in ascending order of the change in mathematics performance among students interested in mathematics.
Source: OECD, PISA 2012 Database Table 4.19.
StatLink *http://dx.doi.org/10.1787/888933377639*

Note

1. This result is robust to accounting for students' performance in mathematics.

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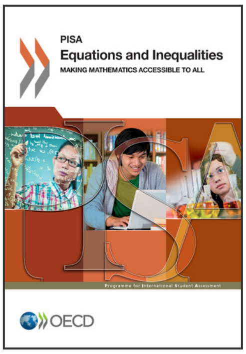

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