2

How schools and teaching practices shape students' performance in and dispositions towards science

This chapter focuses on the opportunity to learn science at school, the school resources devoted to science, and how science is taught in schools. It discusses how these are related to student performance in science, students' epistemic beliefs, and students' expectations of pursuing a career in science. The opportunity to learn science includes the attendance at science courses and the choice of school science courses. The school resources examined include the quality and availability of science laboratories, the qualifications of the science teaching staff, and the availability of science-related extracurricular activities. The methods for teaching science discussed in the chapter include teacher-directed instruction, feedback, adaptive instruction and enquiry-based instruction.

A 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.

Many of the scientific principles and theories that 15-year-olds are familiar with were learned at school. As with any other subject, the way science is taught in school can influence not only whether students do well in science, but also whether they become interested enough in the subject to want to pursue it later on, in further education or in a career. Given the expected growth in science-related employment worldwide (Langdon et al., 2011; Royal Academy of Engineering, 2012) and the declining interest in science as students progress through school (Galton, 2009; Vedder-Weiss and Fortus, 2011), it is important to examine why some students are better prepared for and more interested in science-related careers than others. This means analysing in detail the opportunity to learn science at school, the resources available to the science department, such as laboratories, science teachers and science activities, and the way science is taught at school.

What the data tell us

- The approximately 6% of students across OECD countries who reported not attending any regular science lessons score 25 points lower than students who reported attending at least one science lesson, after accounting for the socio-economic profile of students and schools. In 34 school systems, particularly in Austria, Belgium, Croatia, France, Germany, the Slovak Republic and Chinese Taipei, the students who reported not attending regular science lessons are more likely to attend socio-economically disadvantaged schools than advantaged schools.
- On average across OECD countries, students score higher in science, show stronger epistemic beliefs and are more likely to expect to pursue a science-related career when their school principals reported that the science department in the school is well-equipped and staffed.
- Across OECD countries, socio-economically advantaged schools are considerably more likely to offer science competitions and a science club as school activities than disadvantaged schools.
- How much time students spend learning and how science is taught are more strongly associated with science performance and the expectations of working in a science-related career than how well-equipped and -staffed the science department is, which extracurricular science activities are offered at school and science teachers' qualifications.
- According to students' reports, and on average across OECD countries, teachers in advantaged schools explain or demonstrate a scientific idea (teacher-directed instruction) more frequently than do teachers in disadvantaged schools. Students who reported that their science teachers frequently use these methods and adapt their teaching to meet students' needs score higher in science, show stronger epistemic beliefs and are more likely to expect to pursue a science-related career than students who reported that their teachers use these methods less frequently.

This chapter examines the opportunity to learn science, the science-related educational resources and teaching practices at school (Figure II.2.1) and how they shape students' performance in science, their beliefs about the nature and origin of science knowledge (known as epistemic beliefs) and their expectations of working in a science-related career. The chapter concludes with in-depth analyses of how students perform in science compared with reading and mathematics, and students' expectations of working in science-related occupations. These analyses also consider students' learning time, teachers' participation in professional development activities, and teacher support in science classes, all of which are analysed in greater detail in other chapters.

Epistemology is the theory of the nature, organisation, justifications and sources of human knowledge; in other words, the theory of what knowledge is, how it is acquired and how people know that they have acquired it (BonJour, 2002; Hofer and Pintrich, 1997). PISA 2015 asked students to answer questions about their beliefs about science, including the extent to which they are positively disposed towards scientific reasoning, committed to using empirical evidence as the basis of beliefs, and value critical thinking as a means of establishing the validity of ideas (Table II.2.1; see Volume I for more details).[1] PISA 2015 also asked students about the occupation they expected to be working in by the time they are 30 years old. To measure the extent to which students are open to the idea of pursuing a science-related career in the future, their responses were grouped into major categories of such careers (Table II.2.2; see Volume I for more details).[2]

Figure II.2.2 shows the countries that scored above the OECD average in PISA 2015 in each of these three dimensions: students' performance in science, the level of students' support for scientific approaches to enquiry (their epistemic beliefs), and the share of students who expect to pursue a career in science. The countries with values above the OECD average in all three dimensions are indicated in the centre of the diagram.

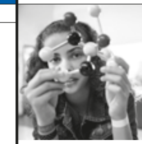


Figure II.2.1 ▪ **Science at school as covered in PISA 2015**

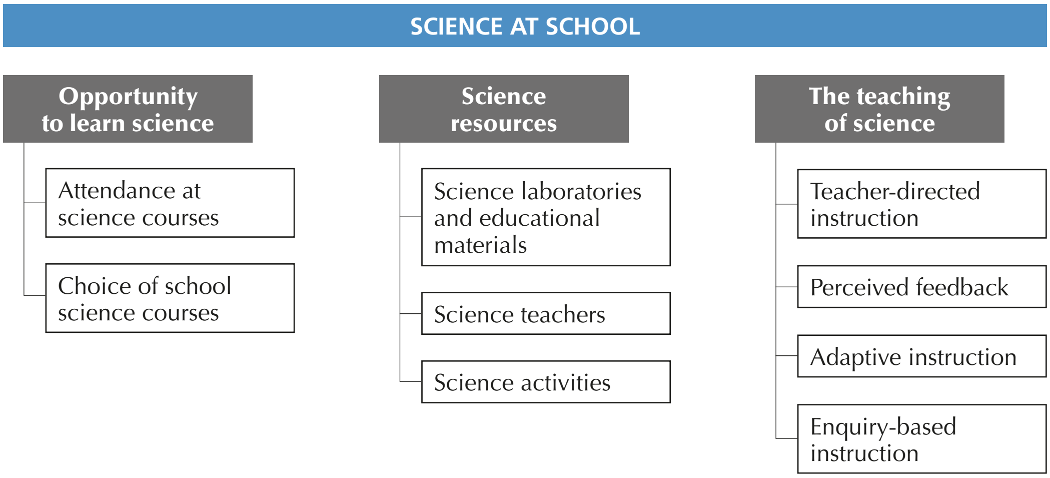
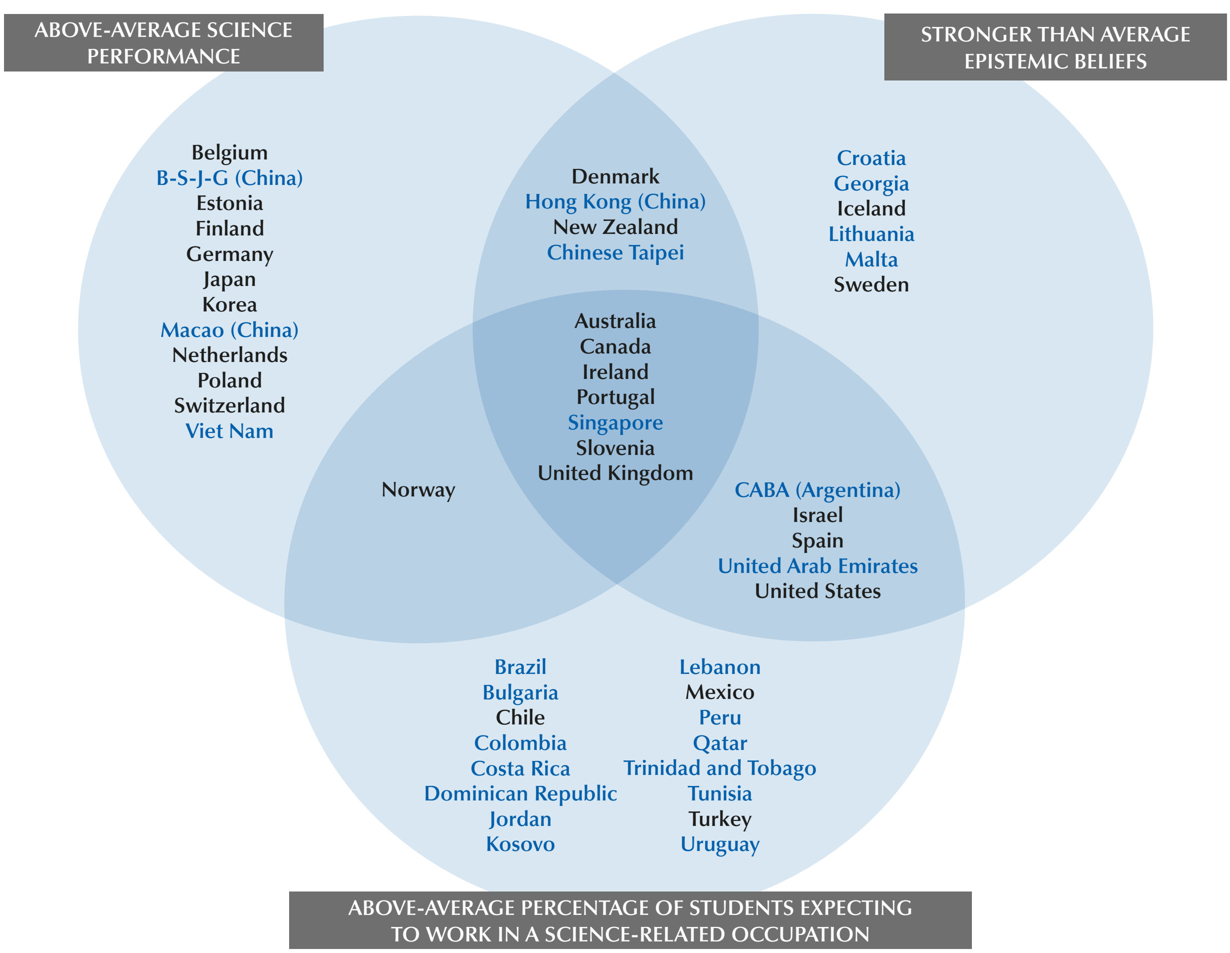


Figure II.2.2 ▪ **High-performing education systems in science-related outcomes**



Note: Average refers to the OECD average for each outcome. Only countries and economies with values above the OECD average are shown.
Source: OECD, PISA 2015 Database, Tables I.2.3, I.2.12a and II.2.2.

The amount and quality of resources (material, human, time) that countries, schools, families and students invest in teaching and learning science play a major role in how well students perform, their level of understanding of how science works, and how interested they may be in working in a science-related career later on. Figure II.2.3 shows how the seven highest-performing countries identified in Figure II.2.2 compare to the OECD average on some key school-resource indicators: the science department and learning time, teaching staff, approaches to science teaching and extracurricular activities. All of these countries score near or above average on most of the resources and practices listed. The figure also underlines the different combinations of resources and practices that are associated with these countries' success.

Figure II.2.3 ▪ **Key information about high-performing education systems in science-related outcomes**

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

	OECD average	Canada	Australia	Portugal	Singapore	United Kingdom	Ireland	Slovenia
The science department and learning time								
Percentage of students in schools whose principal reported that the following statements are true for the school's science department:								
The school science department is well-equipped compared to other departments	**74%**	93%	94%	90%	95%	86%	94%	76%
Science teachers are among our best-educated staff members	**65%**	73%	69%	61%	75%	69%	85%	49%
Compared to similar schools, we have a well-equipped laboratory	**62%**	88%	88%	78%	88%	78%	84%	80%
Average time per week spent learning in regular science lessons, in hours	**3.5**	4.8	3.5	3.7	5.5	4.7	2.4	3.5
Average time per week spent studying science after school (e.g. homework, extra instruction), in hours	**3.2**	4.4	3.4	3.2	5.6	3.7	2.7	3.0
Teaching staff								
Percentage of science teachers with a university degree and a major in science	**74%**	81%	93%	88%	89%	93%	91%	90%
Percentage of science teachers who attended a programme of professional development	**51%**	74%	83%	37%	81%	80%	51%	48%
Approaches to teaching science								
Percentage of students who reported that the following things happen in their science lessons:								
Teacher explains scientific ideas (every or almost every lesson)	**24%**	39%	33%	39%	31%	32%	22%	27%
Teacher adapts the lesson to my class's needs and knowledge (every or almost every lesson)	**16%**	18%	17%	29%	20%	16%	13%	10%
Teacher explains how a science idea can be applied to a number of different phenomena (in all lessons)	**23%**	33%	27%	29%	19%	21%	25%	16%
Teacher tells me how I am performing in this course (at least in some lessons)	**73%**	85%	77%	75%	86%	85%	76%	66%
Students spend time in the laboratory doing practical experiments (at least in some lessons)	**67%**	87%	86%	80%	88%	81%	90%	82%
Extracurricular activities								
Percentage of students in schools offering the following science-related activities:								
Science club	**39%**	57%	38%	57%	42%	79%	35%	52%
Science competitions	**66%**	76%	91%	89%	89%	72%	65%	87%
Science-related outcomes								
Mean score in science	**493**	528	510	501	556	509	503	513
Index of epistemic beliefs	**0.00**	0.30	0.26	0.28	0.22	0.22	0.21	0.07
Percentage of students expecting to work in science-related occupations at age 30	**24%**	34%	29%	27%	28%	29%	27%	31%

Source: OECD, PISA 2015 Database, Tables I.2.3, I.2.12a, II.2.2, II.2.5, II.2.8, II.2.11, II.2.16, II.2.19, II.2.22, II.2.26, II.6.17, II.6.32 and II.6.37.
StatLink http://dx.doi.org/10.1787/888933435461

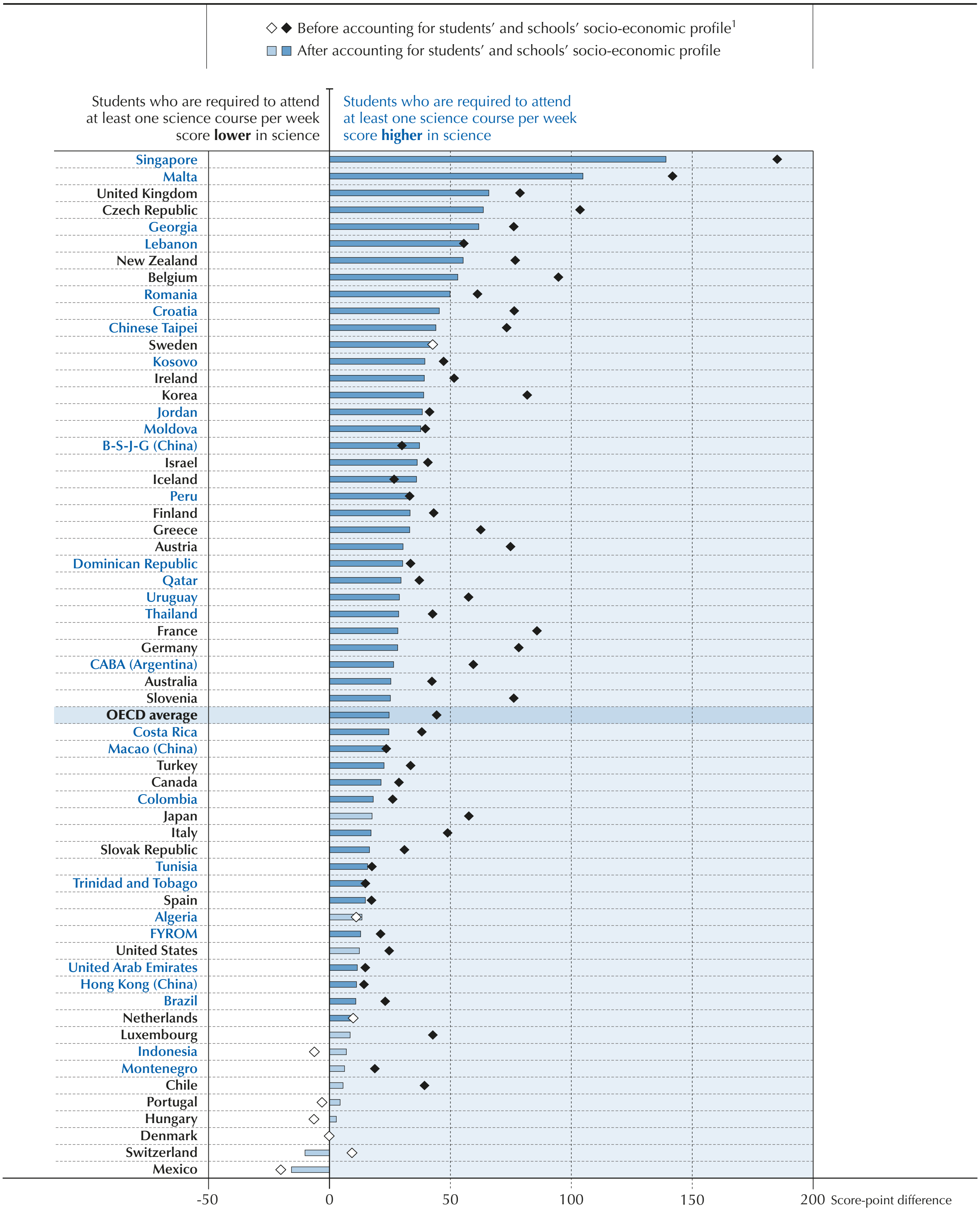
OPPORTUNITY TO LEARN SCIENCE AT SCHOOL

Inequalities in the opportunity to learn, which can be defined as the opportunity to "study a particular topic or learn how to solve a particular type of problem" (Husen, 1967), are mainly reflected in the time education systems, schools and teachers allocate to learning (Carroll, 1963). If time is a necessary condition for learning, students who do not attend science lessons are probably those who enjoy the fewest opportunities to acquire competencies in science.

PISA 2015 asked students how many regular science lessons they were required to attend per week. As expected, most 15-year-old students said they were required to attend at least one science lesson per week. On average across OECD countries, 94% of students reported that they attend at least one science course per week (Table II.2.3). However, there are still 6% of students who said that they are not required to attend any science lesson.

Figure II.2.4 ▪ **Attendance at regular science lessons, and science performance**

Results based on students' reports



1. The socio-economic profile is measured by the PISA index of economic, social and cultural status.

Note: Statistically significant differences are marked in a darker tone (see Annex A3).

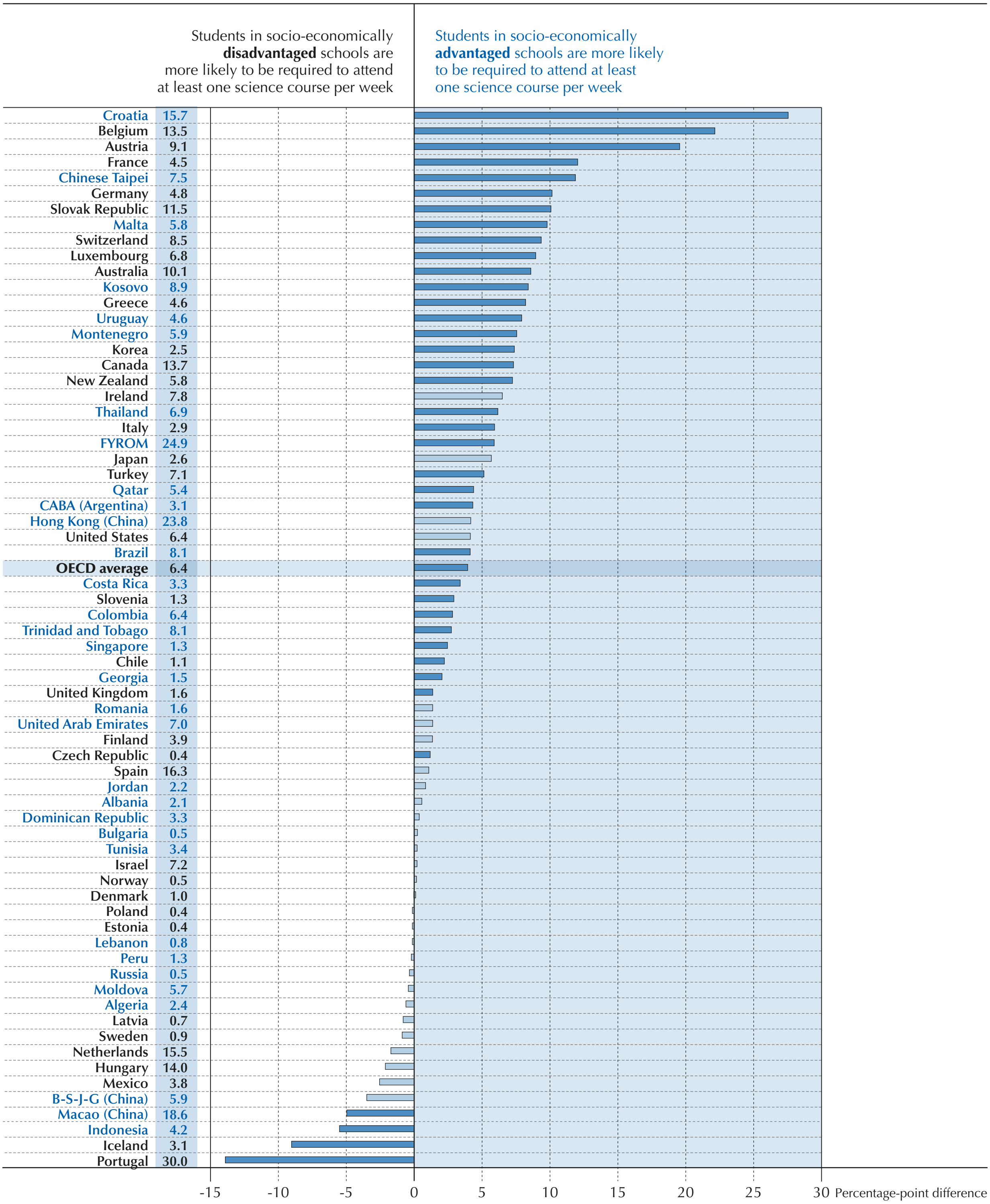
Countries and economies are ranked in descending order of the score-point difference between students who are required to attend a science course and students who are not, after accounting for students' and schools' socio-economic profile.

Source: OECD, PISA 2015 Database, Table II.2.3.

StatLink http://dx.doi.org/10.1787/888933435477

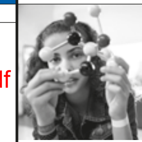
Figure II.2.5 ■ **Differences in the requirement to attend regular science lessons, by schools' socio-economic profile**

Results based on students' reports



Notes: Statistically significant differences are marked in a darker tone (see Annex A3).
The percentage of students who are not required to attend any science course is shown next to the country/economy name.
Countries and economies are ranked in descending order of the percentage-point difference between students in socio-economically advantaged and disadvantaged schools who are required to attend at least one science course per week.
Source: OECD, PISA 2015 Database, Tables II.2.3.

StatLink http://dx.doi.org/10.1787/888933435485



Across OECD countries, students who are not required to attend science lessons score 25 points lower in science than students who are required to attend at least one science lesson per week, after accounting for the socio-economic status of students and schools. The largest differences, before accounting for the socio-economic profile of students and schools, are observed in Singapore, Malta and the Czech Republic, where students who reported that they are not required to attend any science lessons score more than 100 points lower in science than students who reported that they do attend science lessons (Figure II.2.4). Even if their poor performance in science is one of the reasons why these students do not take science courses in the first place – in some education systems, for instance, students can take mainly social sciences and humanities courses in secondary education – these findings indicate the extent to which student performance in science may suffer when students do not attend science classes.

More importantly, students who reported not attending school science classes are more likely to be in schools that are socio-economically disadvantaged (Figure II.2.5) (see Box II.2.1 for a definition of advantaged and disadvantaged schools). On average across OECD countries, students in disadvantaged schools are four percentage points less likely than students in advantaged schools to be required to attend at least one science course. In some education systems, mainly those with early tracking and large between-school differences in performance, such as Austria, Belgium, Croatia, Germany, the Slovak Republic and Switzerland (see Chapter 5), the differences are even larger. Being deprived of science courses in school will not help disadvantaged students close the performance gap with their advantaged peers.

Box II.2.1. **How PISA defines socio-economically advantaged and disadvantaged schools**

All schools in each PISA-participating education syastem are divided into four groups with approximately an equal number of students (quarters), based on the PISA index of economic, social and cultural status (ESCS). Schools in the bottom quarter of ESCS are classified as disadvantaged schools, and schools in the top quarter of ESCS are classified as advantaged schools.

Choice of school science courses

Educators debate how much freedom students should be given to choose what they learn. On the one hand, it is important that students "own" their learning and find ways to pursue their interests and talents. On the other hand, school systems need to ensure that all students acquire strong foundation skills, particularly in core subjects, like science, on which they can later build. Opting out of difficult subjects or courses shuts doors to knowledge that could be of interest – and of use – in the future.

Education systems differ in the extent to which students can choose the science courses they attend, and the courses' level of difficulty and duration (Table II.2.4). In most education systems, students' choices are limited; on average across OECD countries, more than six in ten students have no choice regarding their science courses. In a few education systems, however, there is ample choice. For instance, in Australia, Canada, Hong Kong (China),[3] Ireland, New Zealand and Singapore, more than one in four students reported that they can choose freely the science course(s) they take. In Canada and Ireland, one in three students can also choose freely the course's level of difficulty; and in Canada, one in five students can freely decide the number of science courses or class periods they attend.

Many more students across OECD countries reported that they have some say, as opposed to full freedom, about the science courses they attend (25%), the level of difficulty (26%) or duration of those courses (17%). As expected, on average across OECD countries, students in lower secondary education are less likely to be given the freedom to choose their science courses. For example, 66% of lower secondary students cannot choose at all the science courses they attend, whereas 51% of upper secondary students have some degree of choice. There are smaller differences between the two levels of education when it comes to students choosing the duration or the difficulty of the courses.

SCIENCE RESOURCES AT SCHOOL

Compared with teachers of other school subjects, such as literature, mathematics or geography, science teachers often use expensive and sophisticated equipment in their lessons, particularly if students are expected to participate in laboratory work. At the same time, teachers often mention a lack or inadequacy of resources, in addition to large classes, a lack of time, and safety issues, as barriers to incorporating enquiry-based learning in their lessons (Cheung, 2007; Hofstein and

Lunetta, 2004; Lawson, Costenson and Cisneros, 1986). If students are given sufficient time for reflection and connect their experiments with what they have learned earlier, and if teachers find meaningful ways of assessing their students' laboratory work, conducting experiments can motivate students and improve their understanding of the nature of science (Gunstone and Champagne, 1990; Hofstein and Lunetta, 2004; Tobin, 1990; Yung, 2001). Virtual experiments are often mentioned as a cheaper and safer alternative to physical manipulation; but even if some studies have shown that the two are equally effective in promoting conceptual understanding of science (Zacharias and Olympiou, 2011), real experiments may instil greater motivation in students (Corter et al., 2011).

PISA asked school principals to provide information about the resources available to their school's science department. They were asked if the following eight statements about the science department were true: "Compared to other departments, our science department is well equipped"; "If we ever have some extra funding, a big share goes into improvement of our science teaching"; "Science teachers are among the best-educated staff members"; "Compared to similar schools, we have a well-equipped laboratory"; "The material for hands-on activities in science is in good shape"; "We have enough laboratory material that all courses can regularly use it"; "We have extra laboratory staff that helps support science teaching"; and "Our school spends extra money on up-to-date school science equipment". The index of science-specific resources describes the number of the above questions that the school principal reported to be true for his or her school's science department.

Most school principals in OECD countries reported that the science department is well-equipped and -staffed (Table II.2.5). For example, about three in four principals reported that their science department is well-equipped compared to other school departments or that the material for hands-on activities for science is in good shape; two out of three reported that the school had enough laboratory material that all courses could regularly use it; and around two out of three reported that science teachers were among the best-educated staff members. But only 34% of principals reported that extra laboratory staff is available to support science teaching, and only 39% of principals reported that their school uses a large share of extra funding for improving science teaching. Of course, school principals' judgements may be based on very different benchmarks, usually influenced by their local or national context, so their responses should be interpreted with caution.

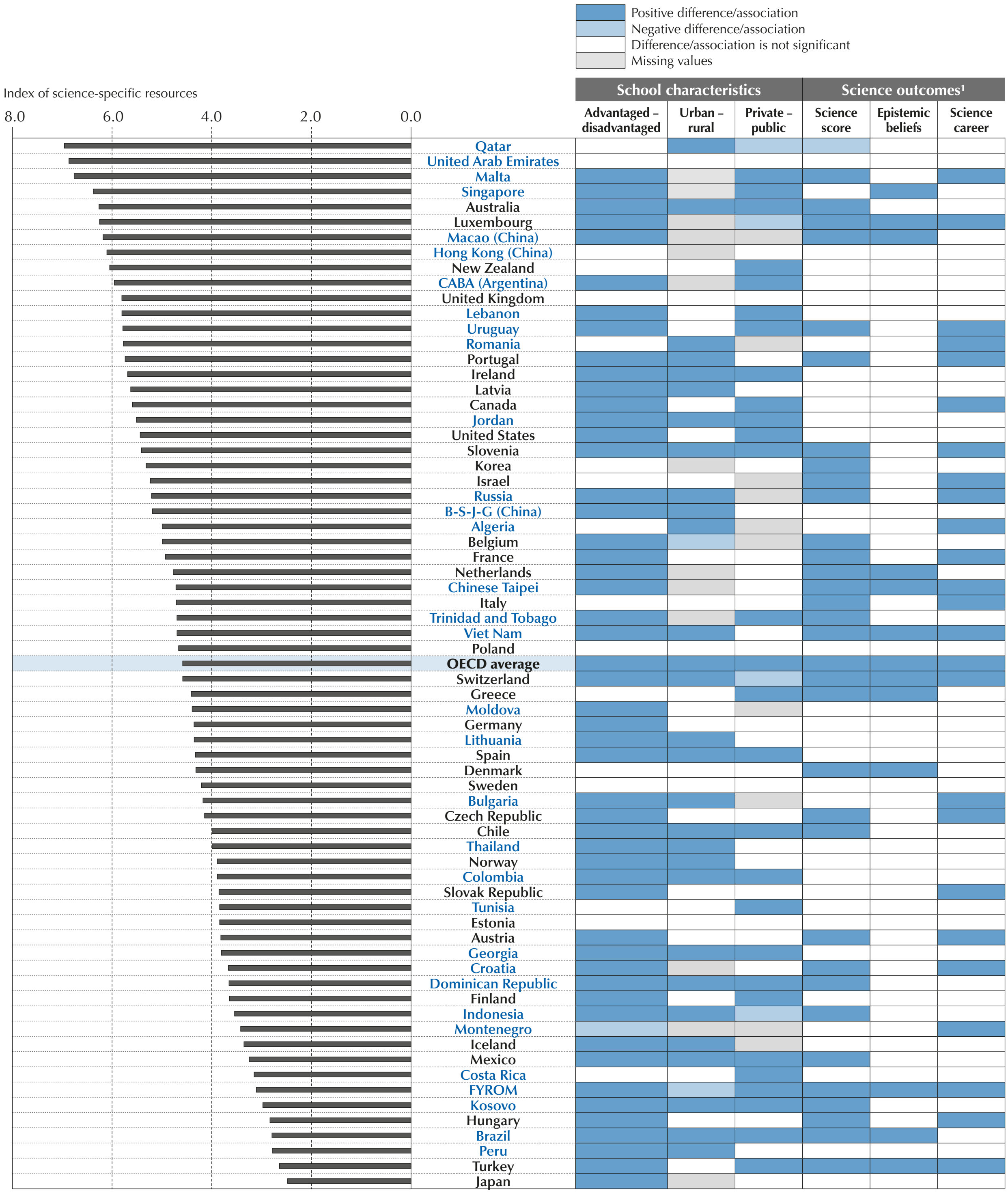
There are also wide differences between countries – differences that are not always related to spending on education or science performance. For instance, in Japan, only 31% of students attend schools whose principal considered that the material for hands-on activities for science is in good shape, and only 30% attend schools whose principals reported that there is enough laboratory material that all courses could regularly use it. Principals in the Czech Republic, Finland, Greece and the Slovak Republic reported that there is almost no extra laboratory staff to support science teaching. By contrast, principals in Malta, Qatar and the United Arab Emirates reported that the science department is well-equipped and -staffed in almost every respect, and is given priority over other departments when there is extra funding (Table II.2.5).

The analysis of the index of science-specific resources in PISA-participating education systems shows consistent differences related to schools' socio-economic profile, school location and school type (Figure II.2.6 and Table II.2.6). For example, on average across OECD countries, principals in socio-economically disadvantaged schools reported that four of the eight positive statements about the resources of the science department are true, whereas principals in advantaged schools reported that five of the eight positive statements are true. Large differences in favour of advantaged schools are observed in Indonesia, Mexico and Chinese Taipei. Only in Montenegro did principals of disadvantaged schools report more frequently than principals of advantaged schools that the science departments in their schools are well-equipped and -staffed.

Principals in urban schools tended to report better resources for the science department than principals in rural schools (Figure II.2.6 and Table II.2.6) (see Box II.2.2 for a definition of urban and rural schools). The largest differences between rural and urban schools (in favour of urban schools) are observed in Chile, Indonesia and Mexico. Overall, private schools are better-equipped and -staffed than public schools (see Box II.2.3 for a definition of public and private schools). The largest differences between the two types of schools (in favour of private schools) in resources available to science departments are observed in the Former Yugoslav Republic of Macedonia (hereafter "FYROM"), Kosovo and Turkey. In Indonesia, Luxembourg, Qatar and Switzerland, science departments in public schools are better-equipped and -staffed than those in private schools.

Figure II.2.6 ■ **Science-specific resources, school characteristics and science outcomes**

Results based on school principals' reports



	Advantaged – disadvantaged	Urban – rural	Private – public	Science score	Epistemic beliefs	Science career
Education systems with a positive difference/association	50	28	27	32	12	24
Education systems with no difference/association	17	25	27	35	56	44
Education systems with a negative difference/association	1	2	4	1	0	0

1. After accounting for the PISA index of economic, social and cultural status of students and schools.

Note: See Annex A7 for instructions on how to interpret this figure.

Countries and economies are ranked in descending order of the index of science-specific resources.

Source: OECD, PISA 2015 Database, Table II.2.6.

StatLink http://dx.doi.org/10.1787/888933435492

Box II.2.2. **How PISA defines urban and rural schools**

PISA asked school principals which of the following definitions best describes the community in which their school is located:

- A village, hamlet or rural area (fewer than 3 000 people)
- A small town (3 000 to about 15 000 people)
- A town (15 000 to about 100 000 people)
- A city (100 000 to about 1 000 000 people)
- A large city (with over 1 000 000 people)

Rural schools are those where the principal answered "a village, hamlet or rural area", whereas urban schools are those where the principal answered either "a city" or "a large city".

Box II.2.3. **How PISA defines public and private schools**

Schools are classified as either public or private, according to whether a private entity or a public agency has the ultimate power to make decisions concerning its affairs (Question SC013). Public schools are managed directly or indirectly by a public education authority, government agency, or governing board appointed by government or elected by public franchise. Private schools are managed directly or indirectly by a non-government organisation, such as a church, trade union, business, or other private institution.

On average across OECD countries, students in schools whose principals reported a well-equipped and well-staffed science department generally perform better in science – by about three score points for every positive statement the school principal reported as true – after accounting for the socio-economic profile of students and schools (Table II.2.6). But having a well-equipped and well-staffed science department is less strongly related to students' beliefs about the nature of scientific knowledge and how it is acquired. In only 12 countries and economies do students hold stronger epistemic beliefs when the science department in their school is well-equipped and -staffed (Figure II.2.6). In 24 education systems, students in schools whose principal reported that the science department enjoys more resources were more likely to report that they expect to work in a science-related occupation in the future.

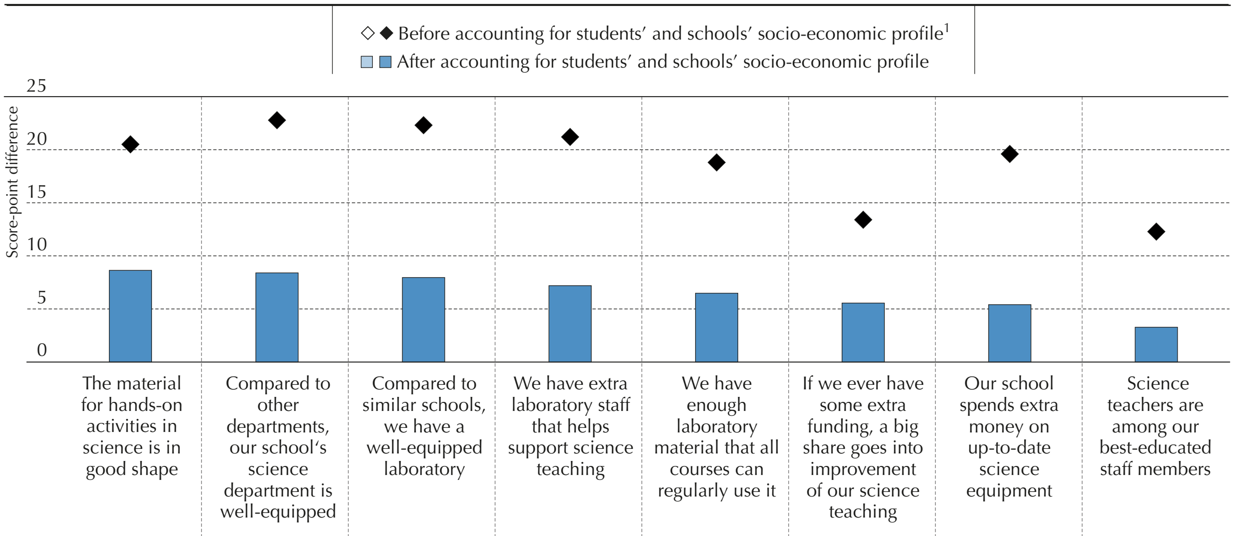
Among the individual questions on resources asked of principals, equipping the science department and laboratories adequately (compared to other school departments and to similar schools), and having materials for hands-on activities that are in good shape are most strongly associated with student performance, after accounting for the socio-economic status of students and schools (Figure II.2.7). On average across OECD countries, students in schools whose principal reported the material for hands-on activities in science is in good shape, score nine points higher on the PISA science assessment. Principals' reports that the school's science teachers are among the best-educated staff members show the weakest association with student performance in science.

Science teaching staff

Since the quality of learning cannot exceed the quality of teaching, science teachers are an essential resource for learning science. The type and quality of the training teachers receive, and the requirements to enter and progress through the teaching profession, can have a significant impact on the quality of teaching. It is difficult to assess the quality of teachers and teaching but, to this end, PISA asked school principals to report on the composition and qualifications of the science teachers in their schools. More specifically, principals were asked how many science teachers had been fully certified – having earned the credentials to teach – by an appropriate authority, and how many science teachers had a university degree with a major in science. In most OECD countries, teachers are required to have earned a university degree and been certified by an education authority; however, many teachers who have earned a university degree do not always need a specific or additional licence to teach, and some fully certified teachers may not have earned a university degree.

Figure II.2.7 ▪ **Science-specific resources at school and science performance**

Results based on school principals' reports, OECD average



1. The socio-economic profile is measured by the PISA index of economic, social and cultural status.
Note: All differences are statistically significant (see Annex A3).
Source: OECD, PISA 2015 Database, Table II.2.7.
StatLink http://dx.doi.org/10.1787/888933435507

According to school principals, most of the science teachers in their schools have some form of certification or qualification. Across OECD countries, 84% of science teachers are fully certified and 74% have a university degree with a major in science (Table II.2.8). The percentage of certified science teachers varies from virtually all teachers in some education systems, including those in Bulgaria, Japan, Lithuania, Macao (China) and Romania, to less than 40% in Chile, Colombia, Georgia and Mexico. Similarly, the percentage of science teachers with a university degree and a major in science ranges from more than 95% of teachers in Bulgaria, Costa Rica and Montenegro, to less than 25% in Italy, Peru and Uruguay.

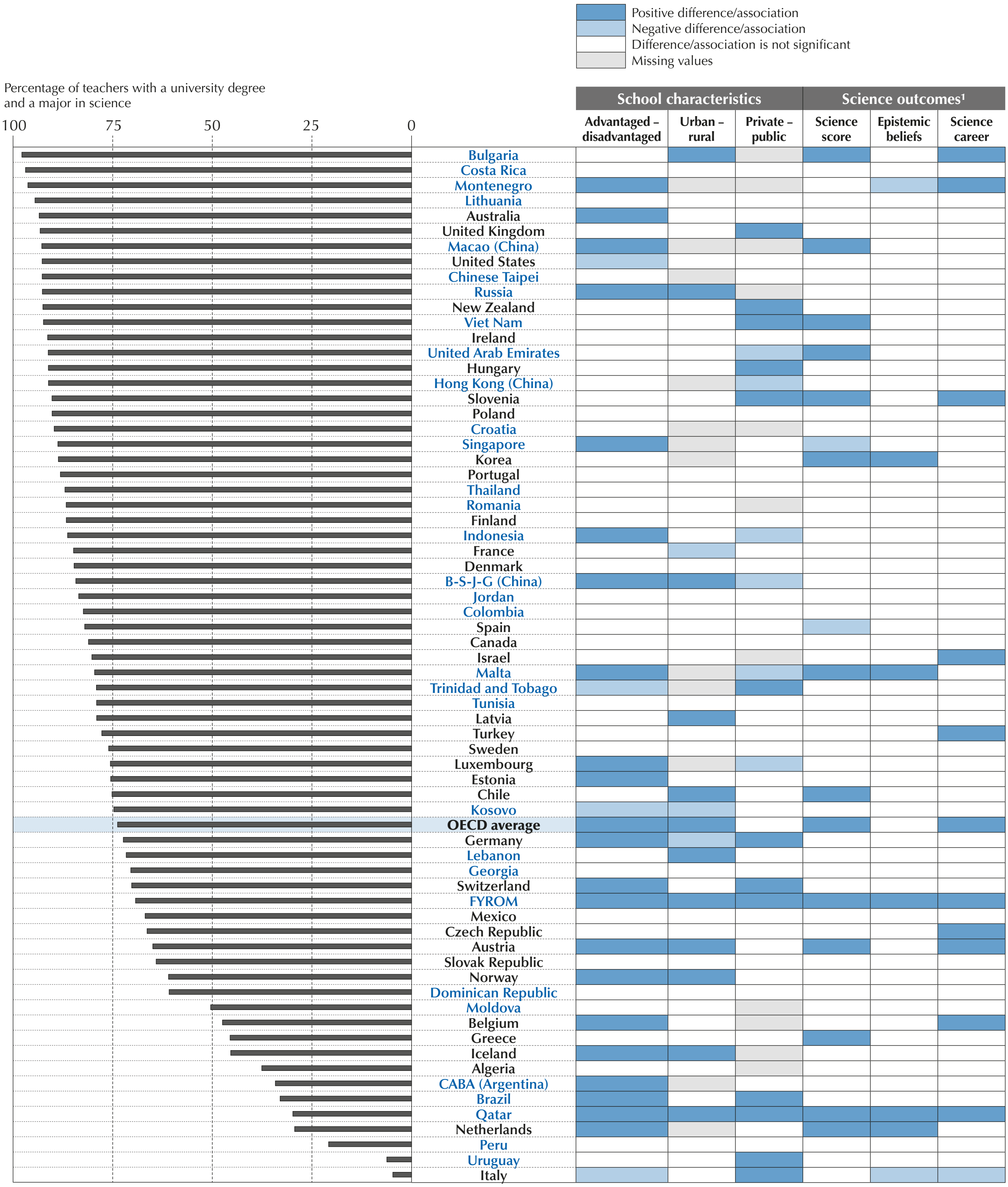
In 20 PISA-participating education systems, advantaged schools have a larger proportion of fully certified science teachers than disadvantaged schools, particularly those in Austria, France and Indonesia (Table II.2.9). In 11 education systems, private schools have a larger proportion of fully certified science teachers than public schools. This difference is particularly striking in the United Arab Emirates and Viet Nam, where there is a 15 percentage-point difference, at least, between private and public schools in the percentage of fully certified science teachers. In 12 countries and economies public schools have a larger proportion of certified science teachers than private schools, particularly so in Costa Rica, FYROM, Indonesia, Italy, and Qatar.

In most education systems, the proportion of fully certified science teachers shows no association with student performance in science (Table II.2.9). Across OECD countries, for every ten percentage-point increase in the number of fully certified science teachers, students' performance in science improves by only 1.2 score points, after accounting for students' and schools' socio-economic profile. The relationship between the proportion of fully certified science teachers and students' epistemic beliefs and their expectation to work in a science-related career appears to be even weaker, given the few countries and economies where there is a relationship. These findings are consistent with some empirical studies showing that teacher certification alone does not automatically raise student achievement (Goldhaber and Brewer, 2000).

Results are similar for the percentage of science teachers with a university degree and a major in science (Figure II.2.8). In most education systems, the proportion of qualified science teachers is similar across all types of schools. However, on average across OECD countries, there are more qualified teachers in advantaged than in disadvantaged schools and in urban than in rural schools. The largest differences between advantaged and disadvantaged schools are observed in Austria, Ciudad Autónoma de Buenos Aires (Argentina) (hereafter "CABA [Argentina]"), the Netherlands and Switzerland, most of which are education systems with early tracking – students are selected into different curricular paths at the age of 10 or 12 (Figure II.5.8) – and considerable between-school differences in performance (Figure II.5.12). How students are selected and grouped across education systems is discussed at length in Chapter 5.

Figure II.2.8 ▪ **Science teachers' qualifications, school characteristics and science outcomes**

Results based on students' self-reports



	Advantaged – disadvantaged	Urban – rural	Private – public	Science score	Epistemic beliefs	Science career
Education systems with a positive difference/association	21	11	13	13	5	10
Education systems with no difference/association	42	41	37	52	60	56
Education systems with a negative difference/association	4	3	6	2	2	1

1. After accounting for the PISA index of economic, social and cultural status of students and schools.

Countries and economies are ranked in descending order of the percentage of science teachers with a university degree and a major in science.

Source: OECD, PISA 2015 Database, Table II.2.10.

StatLink http://dx.doi.org/10.1787/888933435518

On average across OECD countries and in 13 countries and economies, students score higher in science when there is a larger proportion of science teachers with a university degree and a major in science in their schools (Figure II.2.8 and Table II.2.10). In the Netherlands and Qatar, for example, a ten percentage-point increase in the number of science teachers with a university degree and a major in science is associated with an improvement of almost eight score points in science performance, after accounting for the socio-economic profile of both students and schools. However, in most education systems, the percentage of teachers with a university degree and science scores are not related, which is consistent with previous studies showing that just having highly qualified teachers is usually not enough to improve student performance (Hanushek, Piopiunik and Wiederhold, 2014; Palardy and Rumberger, 2008). Similarly, across OECD countries, having a larger proportion of qualified teachers does not necessarily translate into stronger epistemic beliefs among the students in a school, and is only weakly linked to students' expectation to work in a science-related occupation when they are 30.

Extracurricular science activities

Laboratories and experiments are not the only ways through which schools can engage students in learning science. Schools can organise field trips, visits to museums, laboratories or zoos, or can encourage students to participate in science clubs and competitions. These extracurricular activities can help students understand scientific concepts, raise interest in science and even nurture future scientists (Bellipanni and Lilly, 1999; Huler, 1991). Students who participate in science competitions, for instance, show a genuine interest in learning science (Abernathy and Vineyard, 2001; Czerniak and Lumpe, 1996), and both boys and girls develop the desire to understand scientific phenomena (Höffler, Bonin and Parchmann, 2016). Some experts argue that science clubs can also foster greater interest in science by emphasising the fun aspect of school science, especially among minority groups (Thomas, 1986; Yaakobi, 1981).

Principals were asked if their school offers a science club and science competitions at the school. Across OECD countries, 39% of students are enrolled in schools that offer a science club and 66% attend schools that offer science competitions (Figure II.2.9). Science clubs are most commonly offered in East Asian countries and economies. For example, in Beijing-Shanghai-Jiangsu-Guangdong (China) (hereafter "B-S-J-G [China]"), Hong Kong (China) and Korea, more than 90% of students attend schools that offer science clubs. Science competitions, by contrast, are most frequently offered in several Eastern European countries, including Estonia, Hungary, Lithuania, Moldova, Poland and the Russian Federation (hereafter "Russia"), where more than 90% of students attend schools that offer these science activities.

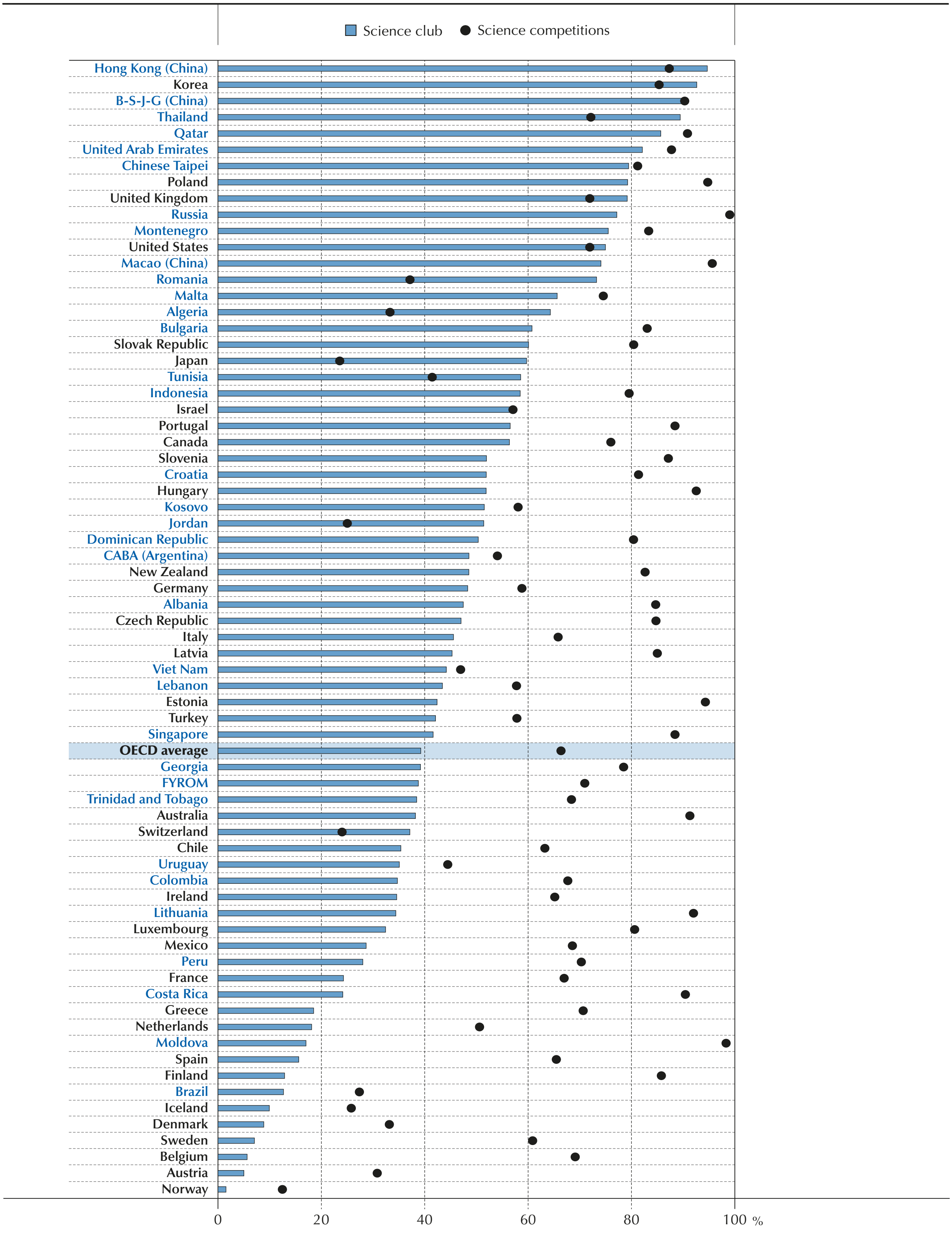
On average across OECD countries, advantaged schools offer science clubs and competitions more often than disadvantaged schools do (Table II.2.12 and Table II.2.13). For example, while 53% of students enrolled in disadvantaged schools are offered science competitions, 78% of students in advantaged schools are offered this activity (Figure II.2.10). In 41 of 69 PISA-participating countries and economies, students attending advantaged schools are offered science competitions more frequently than students attending disadvantaged schools. The largest differences are observed mainly in education systems with early tracking, including Austria, Germany, Luxembourg, the Netherlands and Switzerland.

These large differences suggest than low-performing students in these education systems may have fewer opportunities to acquire scientific competencies, such as by participating in science-related extracurricular activities, than top-performing students. On average across OECD countries, students in schools that offer science competitions score 36 points higher in science (12 points higher after accounting for students' and schools' socio-economic profile) and 21 points higher if the school offers a science club (6 points higher after accounting for students' and schools' socio-economic profile) (Figure II.2.11 and Table II.2.12). The largest differences in performance between students who are offered extracurricular science-related activities and those who are not are observed in the Netherlands and Chinese Taipei. For example, in the Netherlands, students who are offered science competitions score 97 points higher in science than students who are not offered these activities (after accounting for the socio-economic status of students and schools, the former group of students scores 43 points higher). Having access to a science club in Chinese Taipei is associated with scoring 60 score points higher on the PISA science assessment, and 22 score points after accounting for socio-economic status.

Across OECD countries, students who attend schools that offer science-related extracurricular activities hold stronger epistemic beliefs, such as believing that scientific ideas sometimes change or that evidence comes from experiments. In 18 education systems, particularly those in Korea, Montenegro and Thailand, students in schools that offer a science club are more likely to expect to work in science-related occupations, after accounting for the socio-economic status of students and schools (Table II.2.12). In 23 education systems, students in schools that offer science competitions are also more likely to expect to work in a science-related occupation when they are 30 (Table II.2.13).

Figure II.2.9 ■ **Science-related extracurricular activities offered at school**

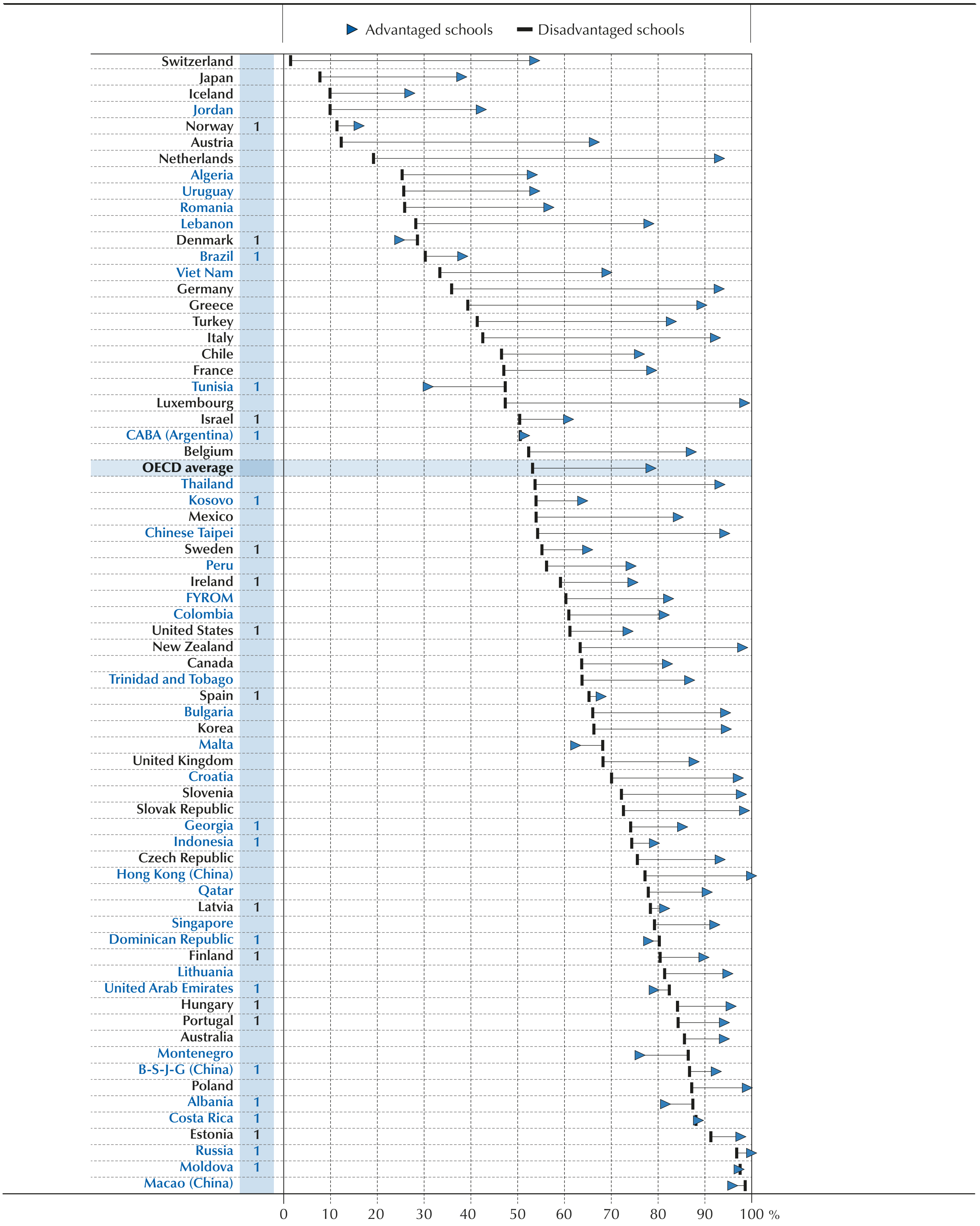
Results based on school principals' reports



Countries and economies are ranked in descending order of the percentage of schools offering a science club.
Source: OECD, PISA 2015 Database, Table II.2.11.
StatLink http://dx.doi.org/10.1787/888933435520

Figure II.2.10 ▪ **Science competitions offered at school, by schools' socio-economic profile**

Results based on school principals' reports



1. Differences between advantaged and disadvantaged schools are not statistically significant (see Annex A3).

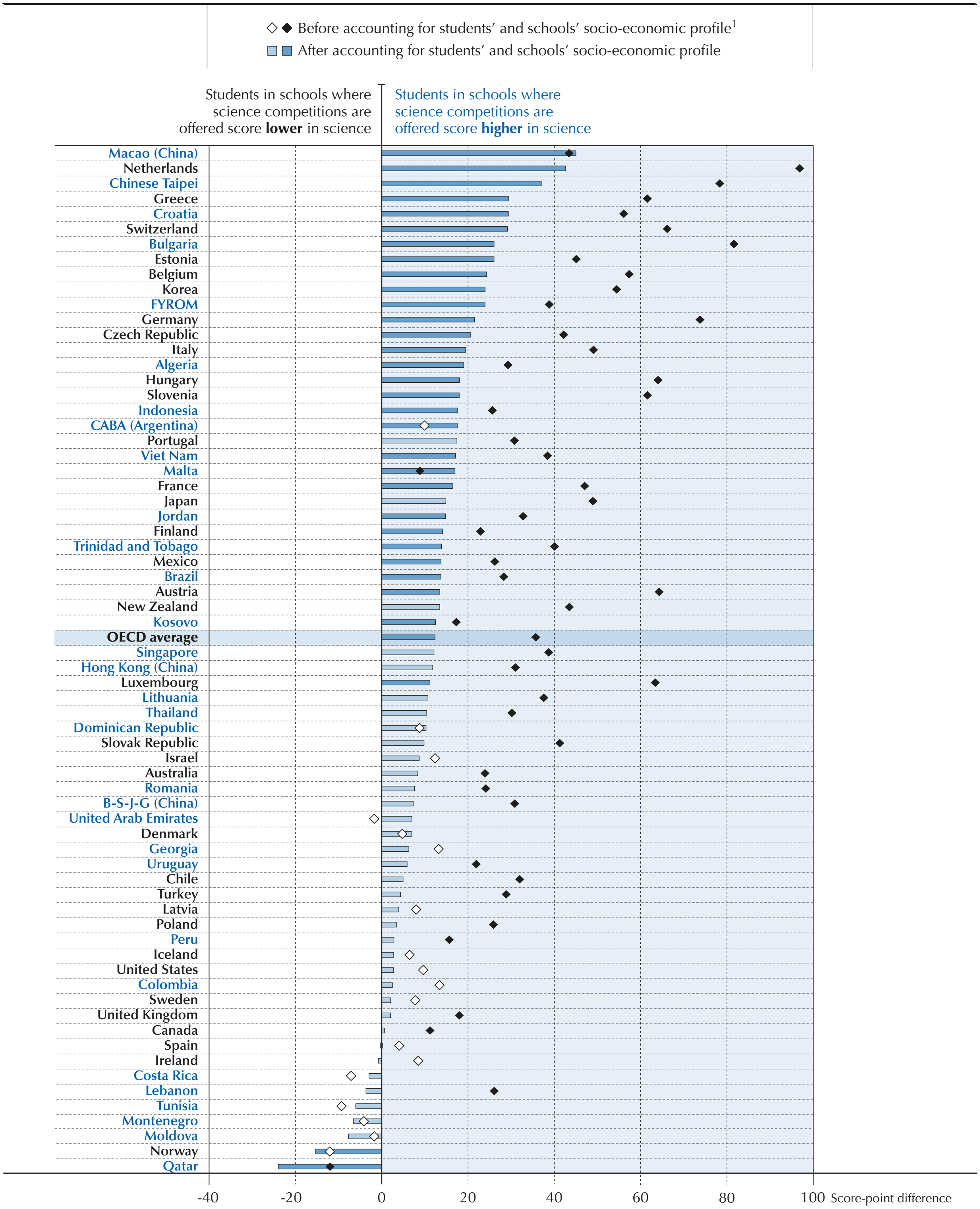
Countries and economies are ranked in ascending order of the percentage of students in disadvantaged schools who are offered science competitions at school.

Source: OECD, PISA 2015 Database, Table II.2.13.

StatLink http://dx.doi.org/10.1787/888933435530

Figure II.2.11 ▪ **Science competitions offered at school and science performance**

Results based on school principals' reports



1. The socio-economic profile is measured by the PISA index of economic, social and cultural status.

Note: Statistically significant differences are marked in a darker tone (see Annex A3).

Countries and economies are ranked in descending order of the score-point difference when science competitions are offered at school, after accounting for students' and schools' socio-economic profile.

Source: OECD, PISA 2015 Database, Table II.2.13.

StatLink http://dx.doi.org/10.1787/888933435544

Surprisingly, students in schools that offer a science club as a school activity are equally likely to participate in a science club as students in schools that do not offer that activity (Table II.2.14). This might be because schools in which students are (not) already attending a science club outside of school may have less (more) incentive to offer a science club themselves.

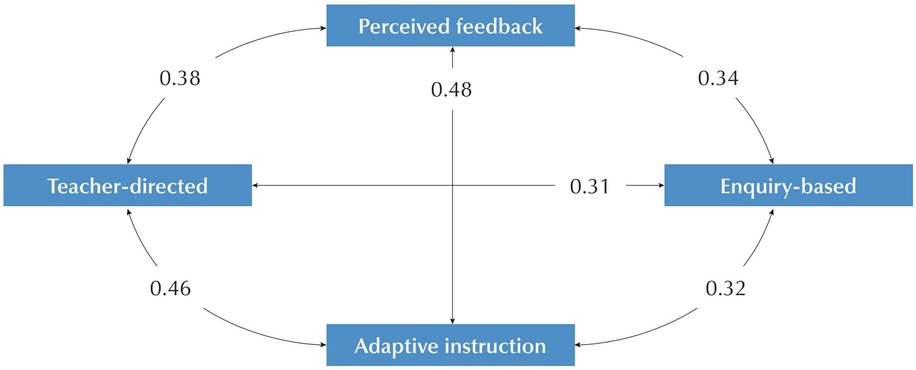
TEACHING SCIENCE

How science is taught at school can make a big difference for students. Education systems, schools and teachers need to decide how much emphasis is given to learning concepts and facts, observing natural phenomena, designing and conducting experiments, and applying scientific ideas and technologies to understand daily life. Science teachers also need to decide which strategies to use in the classroom, and how much time to allocate to each of them; how much time will be devoted to explanations, class discussions, debates, hands-on activities and students' questions; how much feedback they will provide to students; and how flexible their lessons will be. The way science is taught could affect student performance and students' beliefs about and interest in science. Even if there is no single "best" way of teaching, students need teachers who are challenging and innovative in the way they combine different instructional practices, and who can reach all types of learners (OECD, 2016).

PISA 2015 asked students who attend at least one science course how often certain activities happen in their science lessons. While students may not always recall exactly what happens in their science lessons, students' reports are often more reliable than teachers' reports, as teachers will often overstate how much they expose their students to activities that are positively viewed by others (Hodson, 1993). The teaching strategies used by teachers are grouped into four approaches: teacher-directed instruction, perceived feedback, adaptive instruction and enquiry-based instruction. According to students' reports, these teaching approaches are not mutually exclusive, even if some teaching approaches, such as adaptive teaching and providing feedback, are more frequently combined than others (Figure II.2.12).

Figure II.2.12 ▪ **Relationships among instructional practices in science**

Correlations at the student-level based on students' reports, OECD average



Source: OECD, PISA 2015 Database, Table II.2.15.

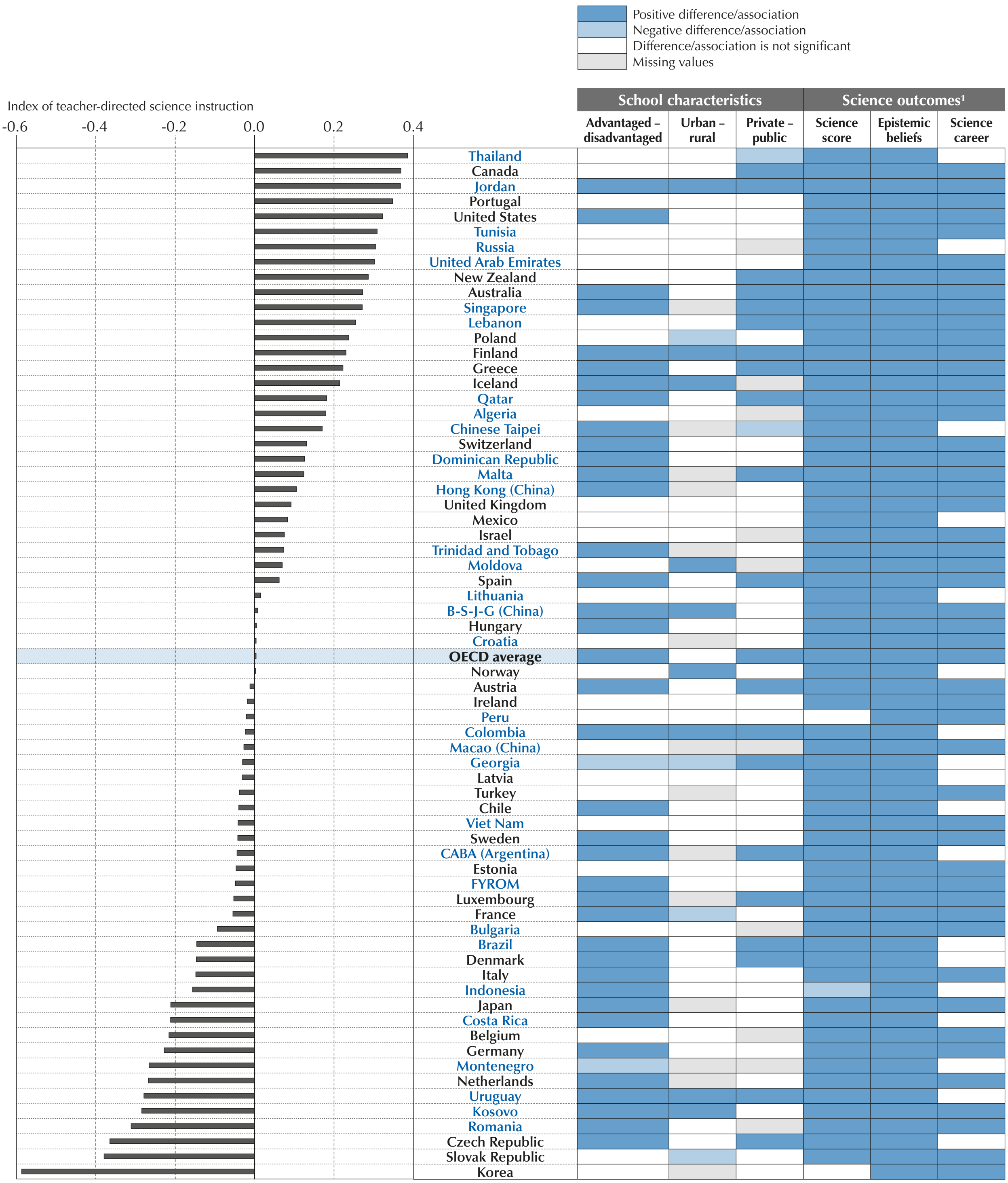
Teacher-directed science instruction

The goal of teacher-directed science instruction is to provide a well-structured, clear and informative lesson on a topic, which usually includes teachers' explanations, classroom debates and students' questions. Even if these strategies render students passive during class, some teacher direction is essential if students are expected to acquire generally accepted science knowledge (Driver, 1995). As with other teaching approaches, much of the effectiveness depends on how well the strategies are used in the classroom.

PISA asked students how frequently ("never or almost never", "some lessons", "many lessons" or "every lesson or almost every lesson") the following events happen in their science lessons: "The teacher explains scientific ideas"; "A whole class discussion takes place with the teacher"; "The teacher discusses our questions"; and "The teacher demonstrates an idea". The index of teacher-directed instruction combines these four questions to measure the extent to which science teachers direct student learning in science lessons. Higher values on this index, and other indices on science instruction, indicate more frequent use of these strategies, according to students' reports.

Figure II.2.13 ▪ **Teacher-directed science instruction, school characteristics and science outcomes**

Results based on students' reports



	Advantaged – disadvantaged	Urban – rural	Private – public	Science score	Epistemic beliefs	Science career
Education systems with a positive difference/association	37	9	20	64	67	49
Education systems with no difference/association	28	40	35	2	0	18
Education systems with a negative difference/association	2	4	2	1	0	0

1. After accounting for the PISA index of economic, social and cultural status of students and schools.

Countries and economies are ranked in descending order of the index of teacher-directed science instruction.

Source: OECD, PISA 2015 Database, Table II.2.17.

StatLink http://dx.doi.org/10.1787/888933435551

Like mathematics teachers (OECD, 2016), science teachers use teacher-directed strategies more frequently than other types of instructional practices (Tables II.2.16, II.2.19, II.2.22 and II.2.26). These strategies may be used more frequently because they are less time-consuming (efficient), they are easier to implement (convenient), and some degree of transmission from knowledgeable others to students is essential, particularly when it comes to scientific knowledge. If a teacher needs to cover a long curriculum, it can be difficult to use other teaching approaches frequently, such as giving individual feedback to students, providing individualised support to struggling students or allowing students to design their own experiments. In fact, among the four teacher-directed strategies, organising "a whole class discussion" is the least frequently used, according to students, probably because it takes up more classroom time.

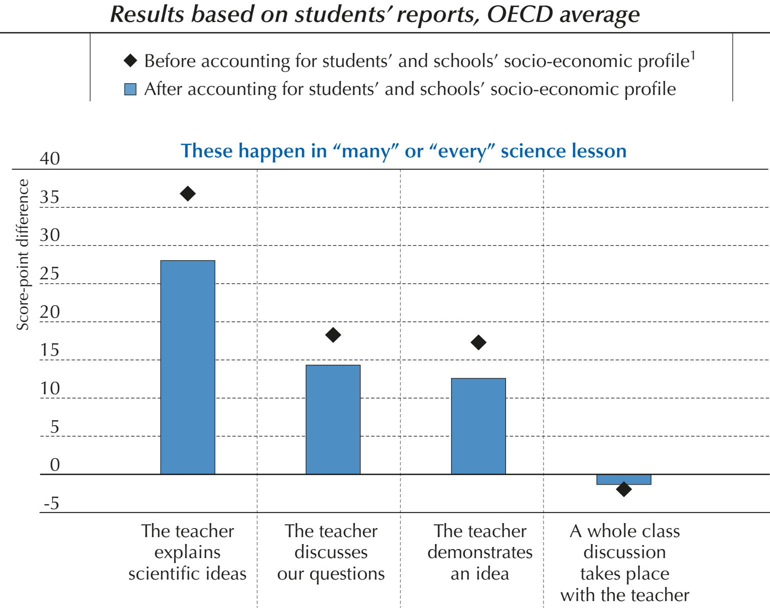
Across OECD countries, teacher-directed instruction is more commonly used in socio-economically advantaged schools than in disadvantaged schools, with the largest differences between the two types of schools observed in B-S-J-G (China), Colombia and Kosovo (Table II.2.17). In 21 countries and economies, these strategies are more frequently used in private schools than in public schools; only in Chinese Taipei and Thailand are they more frequently used in public schools (Figure II.2.13).

In all but three education systems – Indonesia, Korea and Peru – using teacher-directed instruction more frequently is associated with higher science achievement, after accounting for the socio-economic status of students and schools; and students in all countries also hold stronger epistemic beliefs, such as believing that scientific ideas change in light of new evidence, when their teachers used these strategies more frequently (Figure II.2.13). A positive association is also observed between these teaching practices and students' expectations of pursuing science-related careers. In no education system are these instructional practices associated with students being less likely to expect to work in science-related occupations.

On average across OECD countries, and after accounting for the socio-economic status of students and schools, students who reported that their teacher explains scientific ideas "in many lessons" or in "every lesson" score 28 points higher in science; those who reported that their teacher discusses students' questions as frequently score 14 points higher; and students who reported that their teacher demonstrates an idea "in many lessons" or in "every lesson" score 13 points higher in science (Figure II.2.14). However, students score somewhat lower in science when they reported that a whole class discussion occurs "in many lessons" or "every lesson".

Figure II.2.14 ▪ **Teacher-directed teaching practices and science performance**

Results based on students' reports, OECD average



1. The socio-economic profile is measured by the PISA index of economic, social and cultural status.
Note: All differences are statistically significant (see Annex A3).
Source: OECD, PISA 2015 Database, Table II.2.18.
StatLink http://dx.doi.org/10.1787/888933435569

Perceived feedback from science teachers

Providing informative and encouraging feedback is essential for improving student outcomes (Hattie and Timperley, 2007; Lipko-Speed, Dunlosky and Rawson, 2014). Feedback in education usually refers to the information that students receive from peers, parents and teachers after they carry out an assignment, usually some type of assessment. The aim of this information is to modify or reinforce student behaviours. Feedback can take several forms, such as praise, surprise, approval or punishment, but it needs to contain some information about a task (Deci, Koestner and Ryan, 1999). However, not all types of feedback are equally effective. The most useful feedback goes in both directions – from teacher to student and back again – and relates feedback to learning goals (Hattie, 2009).

PISA asked students how frequently ("never or almost never", "some lessons", "many lessons" or "every lesson or almost every lesson") the following happens in their science lessons: "The teacher tells me how I am performing in this course"; "The teacher gives me feedback on my strengths in this class"; "The teacher tells me in which areas I can still improve"; "The teacher tells me how I can improve my performance"; and "The teacher advises me on how to reach my learning goals". The index of perceived feedback combines these five questions to measure the extent to which students perceive that their science teachers provide them with regular feedback.

On average across OECD countries, each of the five types of feedback was reported as being used in every lesson or almost every lesson by fewer than 10% of students; about 20% of students reported that they are used in many lessons. For example, 32% of students reported that their teachers never or almost never tell them in which areas they can still improve or advise them on how to reach their learning goals, and as many as 38% reported that their teachers never give them feedback on their strengths (Table II.2.19). These percentages would probably be higher if teachers were asked about how much feedback they provide as teachers usually say they provide more feedback than what students perceive (Carless, 2006).

Students in disadvantaged and rural schools were more likely to report that their teachers provide them with feedback (Figure II.2.15). More perceived feedback is also associated with poorer performance in science, probably because low-performing students need and receive more feedback than better-performing students. Across OECD countries, the more students perceive that their teachers frequently provide feedback, the more likely they are to expect to work in science-related careers and the stronger their epistemic beliefs.

The relationship with science performance is similar for the different types of perceived feedback (Table II.2.21). Across OECD countries and after accounting for socio-economic status, students score between 5 and 17 points lower in science when they reported that their teachers use these strategies "in many lessons" or "every or almost every lesson" than when they reported that they use them in "some lessons" or "never or almost never".

Adaptive instruction in science lessons

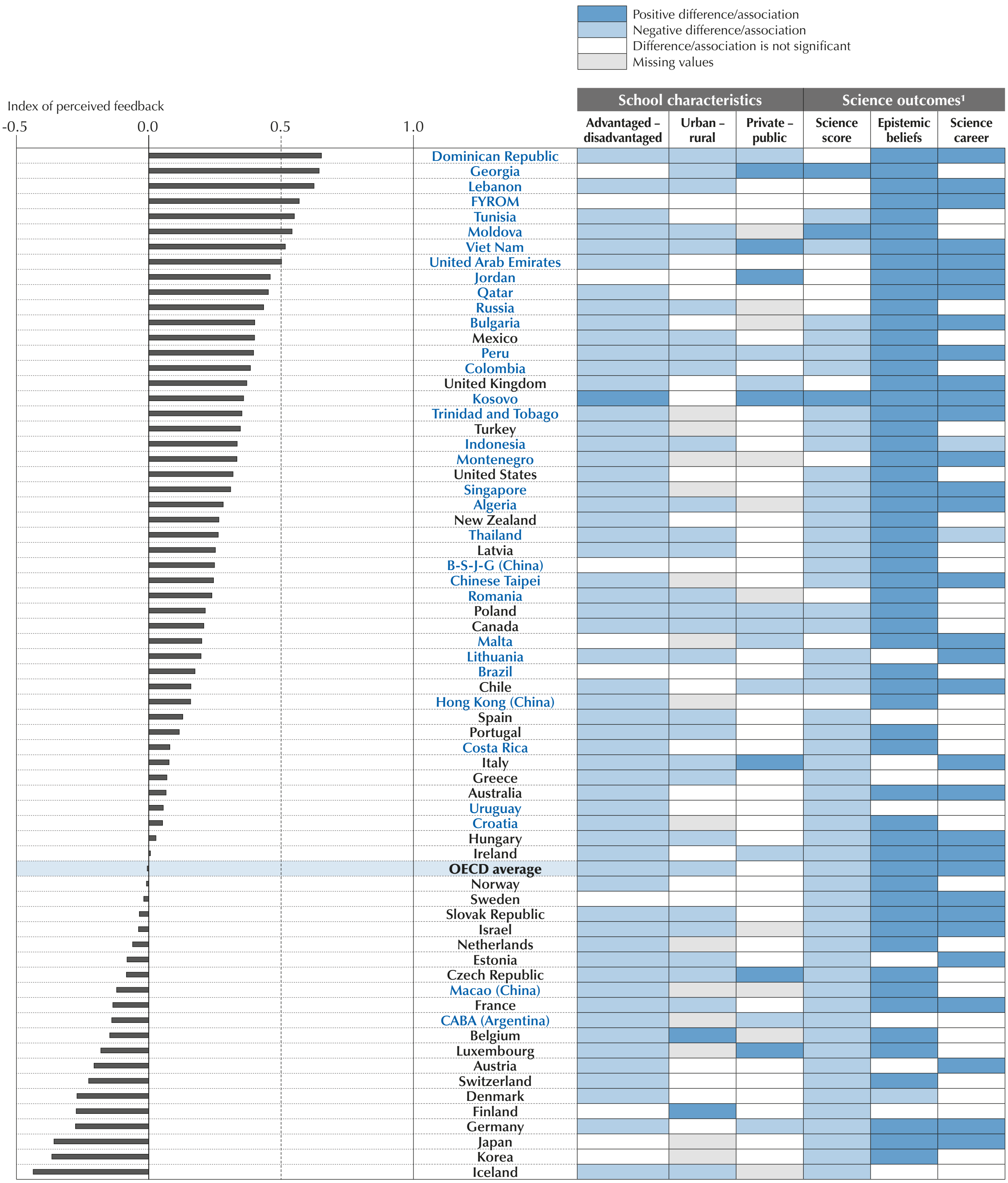
Adaptive instruction refers to teachers' flexibility with their lessons: tailoring the lessons to the students in their classes, including to individual students who are struggling with a topic or a task. Adapting science lessons to students with different knowledge, abilities and needs is crucial if the goal is to teach science to all types of students (Hofstein and Lunetta, 2004).

PISA asked students how frequently ("never or almost never", "some lessons", "many lessons" or "every lesson or almost every lesson") the following happens in their science lessons: "The teacher adapts the lesson to my class's needs and knowledge"; "The teacher provides individual help when a student has difficulties understanding a topic or task"; and "The teacher changes the structure of the lesson on a topic that most students find difficult to understand". The index of adaptive instruction combines these three questions to measure the extent to which students perceive that their science teachers adapt their instruction based on students' needs, knowledge and abilities.

Across OECD countries, about 16% of students reported that their science teachers adapt their instruction in every lesson or almost every lesson, and almost 30% reported their teachers do so in many lessons (Table II.2.22). These percentages vary little across the three questions, even if "[providing] individual help when a student has difficulties" is done somewhat more frequently than "[adapting] the lesson to the student needs and knowledge" and "[changing a lesson when] students find it difficult to understand". Portugal stands out as the country where teachers are more likely to adapt the content and structure of the lesson to the needs, knowledge and abilities of their students. For example, more than one in three students reported that their teacher provides individual help when a student has trouble understanding a topic or task in every lesson or almost every lesson, compared with about one in six students across OECD countries.

Figure II.2.15 ■ **Perceived feedback, school characteristics and science outcomes**

Results based on students' reports



	Advantaged – disadvantaged	Urban – rural	Private – public	Science score	Epistemic beliefs	Science career
Education systems with a positive difference/association	1	2	7	3	56	31
Education systems with no difference/association	10	23	40	12	10	34
Education systems with a negative difference/association	56	28	10	52	1	2

1. After accounting for the PISA index of economic, social and cultural status of students and schools.

Countries and economies are ranked in descending order of the index of perceived feedback.

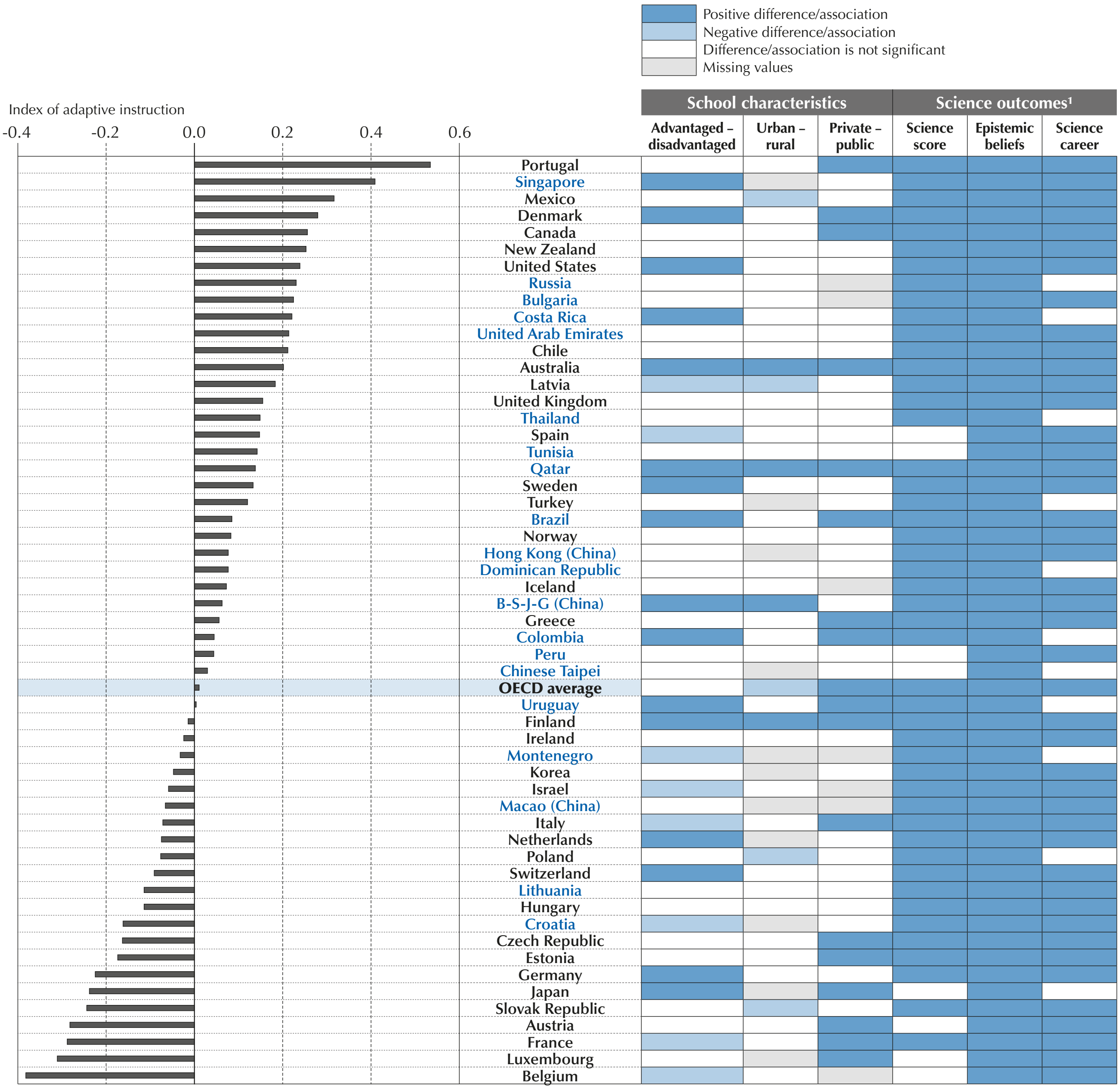
Source: OECD, PISA 2015 Database, Table II.2.20.

StatLink http://dx.doi.org/10.1787/888933435578

Across PISA-participating countries and economies, there is no consistent pattern in how adaptive teaching varies between advantaged and disadvantaged schools or between rural and urban schools (Figure II.2.16). However, in 17 countries and economies, adaptive instruction is more frequently used in private schools than in public schools, particularly in Brazil, Denmark, Greece, Italy, Japan and Portugal. Perhaps in these education systems public school teachers are constrained by the size of their classes and the official curriculum in a way that teachers in private schools are not. It could also be that teachers in private schools have more incentive to adapt their instruction to their students' needs.

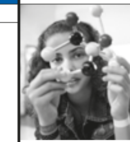
Figure II.2.16 ■ **Adaptive instruction, school characteristics and science outcomes**

Results based on students' reports



	Advantaged – disadvantaged	Urban – rural	Private – public	Science score	Epistemic beliefs	Science career
Education systems with a positive difference/association	16	0	17	46	54	43
Education systems with no difference/association	30	35	30	8	0	11
Education systems with a negative difference/association	8	4	0	0	0	0

1. After accounting for the PISA index of economic, social and cultural status of students and schools.
Countries and economies are ranked in descending order of the index of adaptive instruction.
Source: OECD, PISA 2015 Database, Table II.2.23.
StatLink http://dx.doi.org/10.1787/888933435580



Interestingly, in almost every education system that participated in PISA 2015, students who reported that their science teachers use adaptive instruction more frequently score higher on the PISA science assessment; and in every education system, these students also hold stronger epistemic beliefs (Figure II.2.16). The association with student performance is particularly strong in the Nordic countries and in the Netherlands, Qatar, Singapore and the United Arab Emirates, while the association with epistemic beliefs is strongest in the Dominican Republic, Qatar and the United Arab Emirates (Table II.2.23). Students who reported that their teachers adapt their instruction more frequently also hold higher expectations of pursuing science-related careers.

On average across OECD countries, and after accounting for students' and schools' socio-economic profile, students score 20 points higher in science when they reported that their teachers adapt the lesson to the class's needs and knowledge "in many lessons" or "every lesson" than when they reported that this happens "in some lessons" or "never". Students also score 13 points higher, on average, when they reported that their teacher provides individual help when a student has difficulties understanding a topic or task, and 8 points higher, on average, when their teacher changes the structure of the lesson on a topic that most students find difficult to understand (Table II.2.24).

One way education systems may encourage their teachers to tailor their teaching to students' needs is by granting schools greater autonomy. More autonomy could imply greater incentives for schools and teachers to adapt to their students' needs, rather than simply stick to a detailed curriculum. Figure II.2.17 shows that, on average across OECD countries, more school autonomy is associated with more frequent use of adaptive instruction (tailoring teaching to students' needs and helping students who struggle in a specific task). The relationship is moderate (and negative in Ireland), after accounting for socio-economic status; but changing what happens inside the classroom by changing education policies is never easy (Tyack and Cuban, 1995).

Enquiry-based science instruction

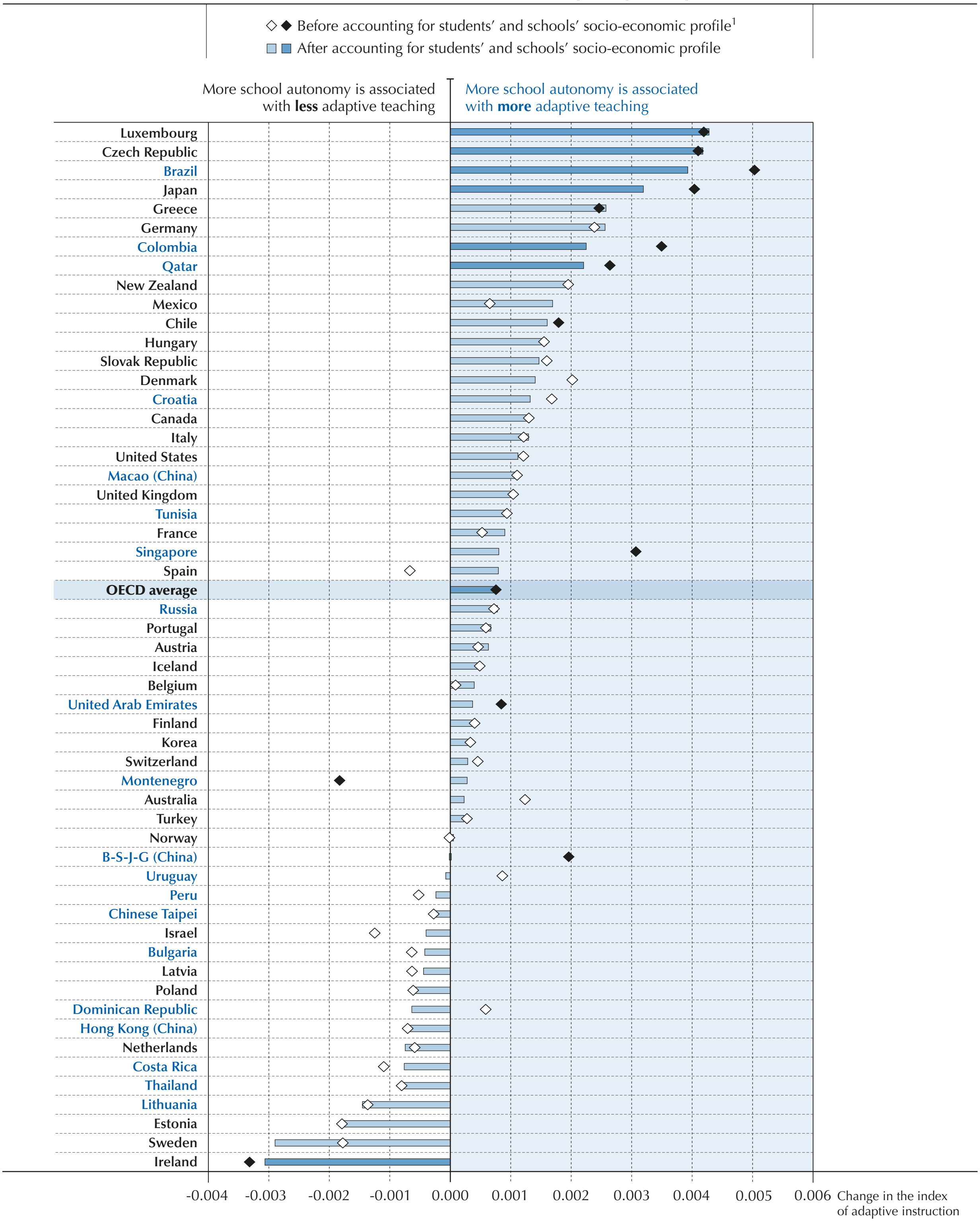
Enquiry-based teaching practices are particularly important in teaching physical and life sciences. Enquiry refers to the ways in which scientists "study the natural world, propose ideas, and explain and justify assertions based upon evidence derived from scientific work" (Hofstein and Lunetta, 2004). In science education, enquiry-based instruction is about engaging students in experimentation and hands-on activities, and also about challenging students and encouraging them to develop a conceptual understanding of scientific ideas. Top-performing students in science are expected to understand, explain and debate scientific ideas; design and carry out experiments and communicate findings; and connect their scientific ideas and investigations to real-life problems (Minner, Levy and Century, 2010). Previous studies show that enquiry-based instruction can improve students' learning, their attitudes towards science, and their transferable skills, such as critical thinking (Blanchard et al., 2010; Furtak et al., 2012; Hattie, 2009; Minner, Levy and Century, 2010). However, some experts caution that laboratory work can only improve learning if it is carefully designed and well-structured, and if students manipulate ideas, not only objects (Hofstein and Lunetta, 2004; Woolnough, 1991).

Many science teachers do not use enquiry-based instructional practices – even some of those who believe they do (Gardiner and Farragher, 1999; Hodson, 1993). Teachers may not propose more enquiry-based learning and laboratory work because of a lack of time and materials, large classes, safety issues, pedagogical limitations, management problems, and teachers' beliefs about students' abilities and the nature of laboratory work (Backus, 2005; Cheung, 2007; Gallet, 1998). Some teachers believe that the typical student is incapable of designing and conducting enquiry activities successfully; others believe that laboratory work is time-consuming and often chaotic (Brown et al., 2006).

PISA asked students how frequently ("never or hardly ever", "in some lessons", "in most lessons" and "all lessons") the following happens in their science lessons: "Students are given opportunities to explain their ideas"; "Students spend time in the laboratory doing practical experiments"; "Students are required to argue about science questions"; "Students are asked to draw conclusions from an experiment they have conducted"; "The teacher explains how a science idea can be applied to a number of different phenomena"; "Students are allowed to design their own experiments"; "There is a class debate about investigations"; "The teacher clearly explains the relevance of science concepts to our lives"; and "Students are asked to do an investigation to test ideas". The index of enquiry-based instruction combines these nine statements to measure the extent to which science teachers encourage students to be deep learners and to enquire about a science problem using scientific methods, including experiments.

Figure II.2.17 ▪ **School autonomy and adaptive instruction in science lessons**

Results based on students' and school principals' reports



1. The socio-economic profile is measured by the PISA index of economic, social and cultural status.

Note: Statistically significant differences are marked in a darker tone (see Annex A3).

Countries and economies are ranked in descending order of the change in the index of adaptive teaching when the index of school autonomy increases by one unit, after accounting for students' and schools' socio-economic profile.

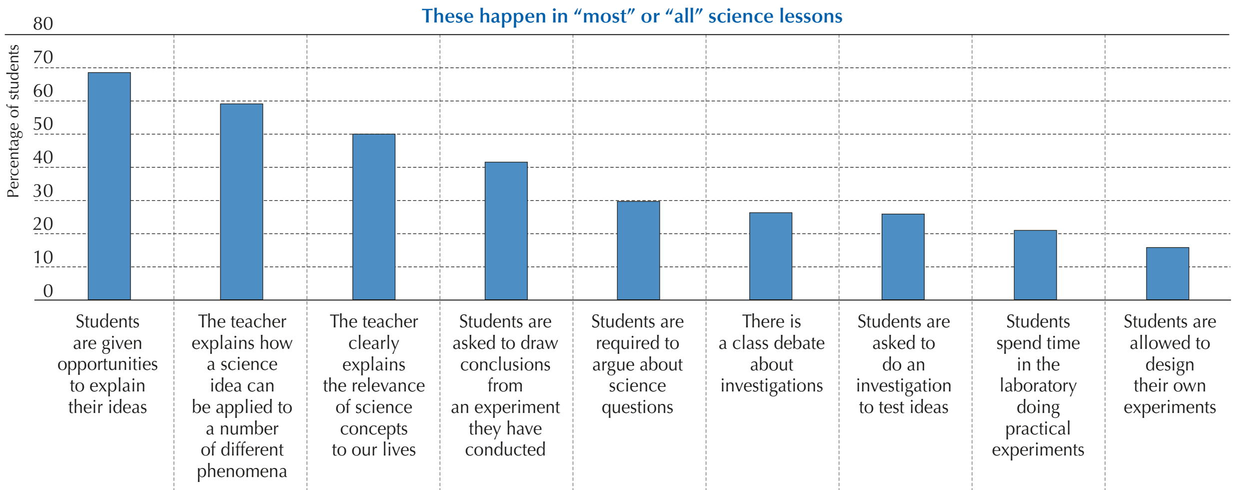
Source: OECD, PISA 2015 Database, Table II.2.25.

StatLink http://dx.doi.org/10.1787/888933435599

When students in OECD countries were asked about what happens in all or most lessons, almost seven in ten reported that they are given opportunities to explain their ideas, about six in ten reported that their science teachers explain how a science idea can be applied to different phenomena, and half reported that their teachers explain the relevance of science concepts to their lives (Figure II.2.18). Only one in four students or fewer reported that they are allowed to design their own experiments or spend time in the laboratory doing practical experiments. Among students who attend at least one science course, at least six in ten students in Brazil, Costa Rica, Iceland, Montenegro, Poland and Spain reported that they never or hardly ever spend time in the laboratory doing practical experiments; and in Austria, Belgium, Finland, Italy, Japan, Korea and the Slovak Republic, more than one in two students reported that they are never or hardly ever asked to do an investigation to test ideas (Table II.2.26).

Figure II.2.18 ▪ **Enquiry-based instruction in science lessons**

Results based on students' reports, OECD average



Source: OECD, PISA 2015 Database, Table II.2.26.
StatLink http://dx.doi.org/10.1787/888933435602

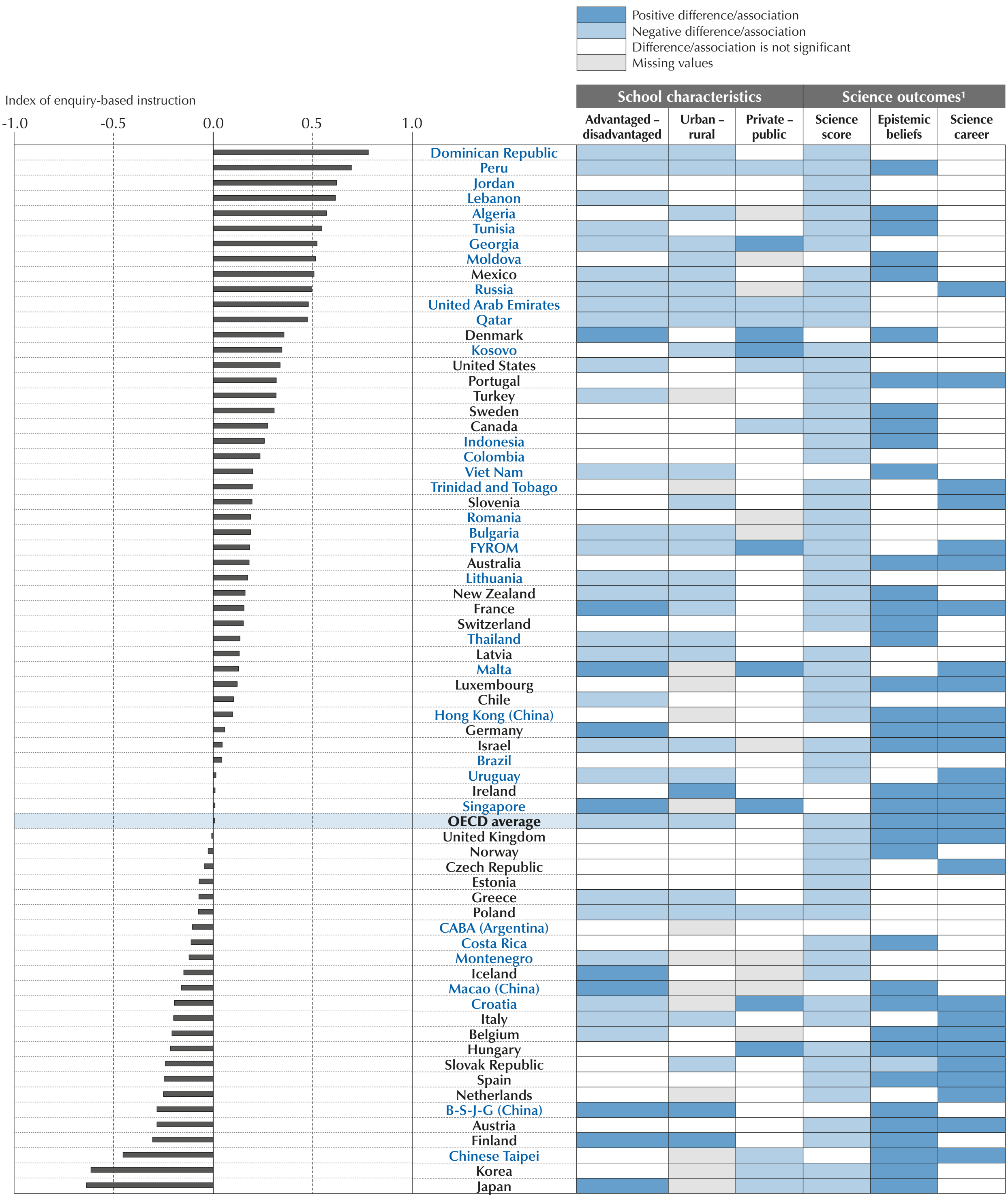
In 27 PISA-participating countries and economies, students in socio-economically disadvantaged schools are more frequently exposed to enquiry-based teaching than those in advantaged schools, while the reverse is true in 10 other education systems (Figure II.2.19). There are also more education systems where enquiry-based teaching is more commonly used in rural schools than in urban schools. But there is no clear pattern in the use of enquiry-based instruction when comparing public and private schools.

After accounting for students' and schools' socio-economic profile, greater exposure to enquiry-based instruction is negatively associated with science performance in 56 countries and economies. Perhaps surprisingly, in no education system do students who reported that they are frequently exposed to enquiry-based instruction score higher in science. However, across OECD countries, more frequent enquiry-based teaching is positively related to students holding stronger epistemic beliefs and being more likely to expect to work in a science-related occupation when they are 30, even if these relationships are weaker than is the case with teacher-directed and adaptive instruction.

Not all of the questions that were used to create the index of enquiry-based instruction are related to performance in the same way (Figure II.2.20). Students who reported that their teachers explain how a science idea can be applied to a number of different phenomena in most or all science lessons score higher in science than do students who reported that such activity happens in some lessons, hardly ever or never. At the other end of the spectrum, activities related to experiments and laboratory work show the strongest negative relationship with science performance. While this correlational evidence should be interpreted with caution – for instance, teachers may be using hands-on activities to make science more attractive to disengaged students (see Figure II.2.21 for a more sophisticated analysis) – it does suggest that some of the arguments against using hands-on activities in science class should not be completely disregarded. These include that these activities do not promote deep knowledge, that they are an inefficient use of time, or that they only work when there is good laboratory material and teacher preparation.

Figure II.2.19 ▪ **Enquiry-based instruction, school characteristics and science outcomes**

Results based on students' reports



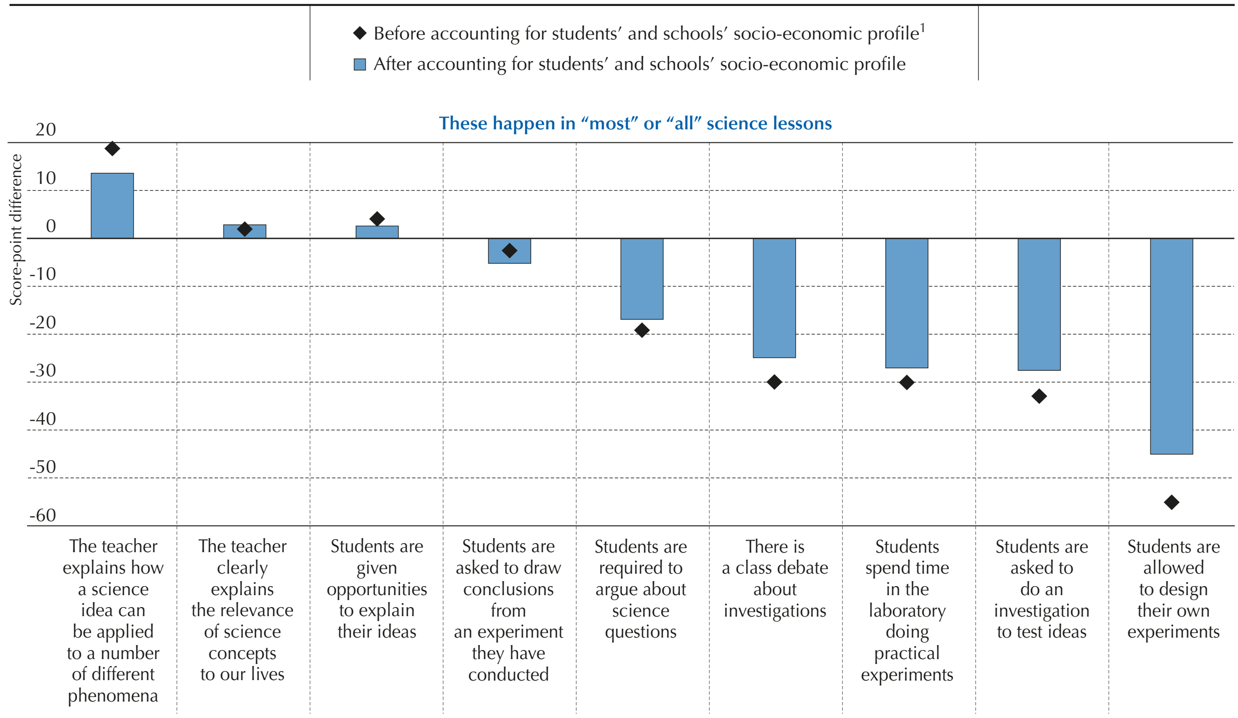
	Advantaged – disadvantaged	Urban – rural	Private – public	Science score	Epistemic beliefs	Science career
Education systems with a positive difference/association	10	3	8	0	36	26
Education systems with no difference/association	31	26	41	12	31	42
Education systems with a negative difference/association	27	25	9	56	1	0

1. After accounting for the PISA index of economic, social and cultural status of students and schools.
Countries and economies are ranked in descending order of the index of enquiry-based instruction.
Source: OECD, PISA 2015 Database, Table II.2.27.

StatLink http://dx.doi.org/10.1787/888933435615

Figure II.2.20 ▪ **Enquiry-based teaching practices and science performance**

Results based on students' reports, OECD average



1. The socio-economic profile is measured by the PISA index of economic, social and cultural status.

Note: All differences are statistically significant (see Annex A3).

Source: OECD, PISA 2015 Database, Table II.2.28.

StatLink http://dx.doi.org/10.1787/888933435628

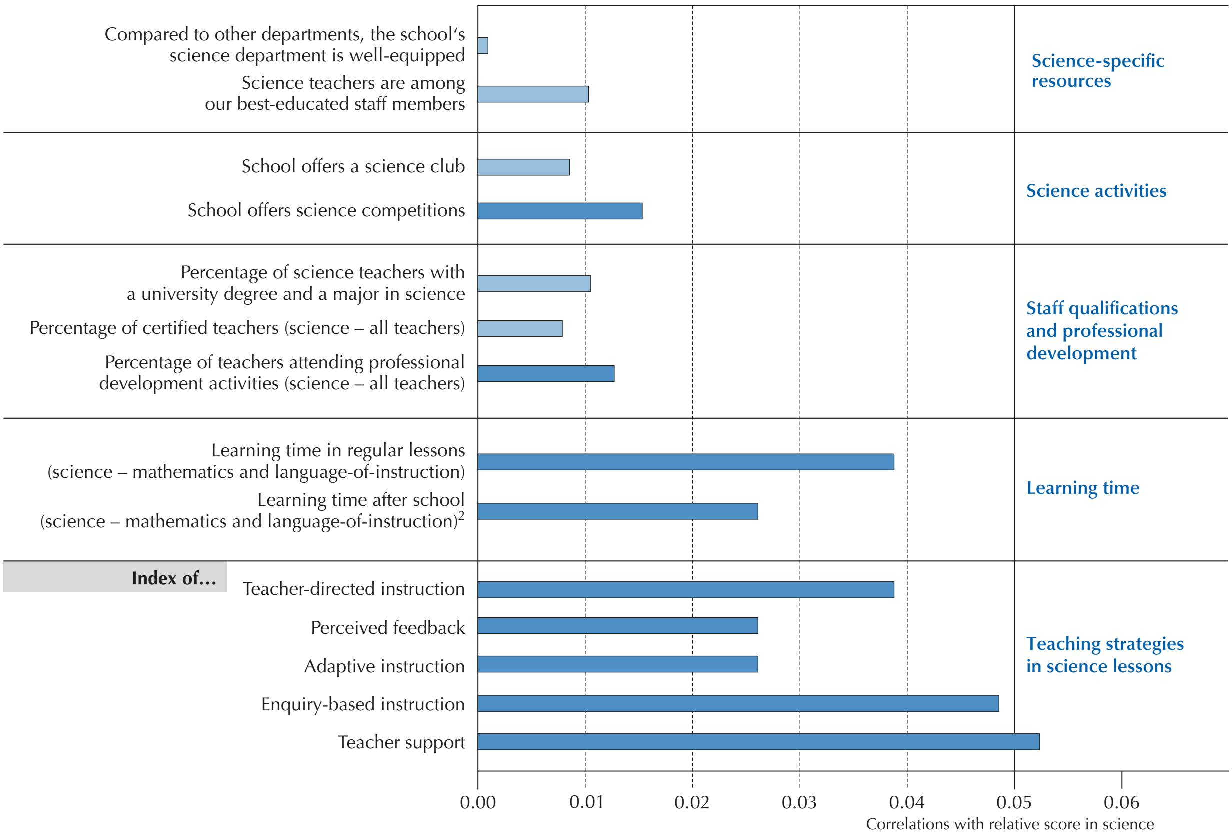
HOW SCIENCE RESOURCES, LEARNING TIME AND TEACHING ARE RELATED TO SCIENCE PERFORMANCE COMPARED TO PERFORMANCE IN OTHER SUBJECTS

Students who perform well in a school subject are more likely to perform well in other school subjects too (see Volume I). For this reason, it is interesting to take an in-depth look at the differences between student performance in science and in other school subjects, such as mathematics and reading, and relate these differences to the resources and teaching devoted to science at school. Some of the analyses in this section provide an even wider perspective as they also compare the material resources and staff in the science department with that in other school departments, and the learning time allocated to science and other subjects. Since the performance of the same students is compared across different subjects, these analyses account for students' characteristics that are important for success in all school subjects and cannot be easily observed, such as their general intelligence or their general perseverance. The explained variable in the analyses presented in Figure II.2.21 is the students' science score minus the average of their scores in reading and mathematics.

The main message that emerges from Figure II.2.21 is that the quality of the material and human resources of a science department, and the kinds of science activities offered to students have a weaker impact on student performance than how much time students devote to learning science and how teachers teach science. Students score higher in science than in reading and mathematics when their school offers science competitions, and when the proportion of science teachers participating in professional development activities is larger than the proportion of all school teachers who have participated in such activities. Students also perform better in science than in mathematics and reading when they spend more time learning science than learning reading and mathematics (both in regular lessons and after school), and when their teachers frequently use any of the five teaching approaches analysed – but especially those categorised as teacher-support or enquiry-based instruction.[4] The correlations are weak, but this is to be expected given that a range of student characteristics, such as their socio-economic status and general intelligence, are accounted for.

Figure II.2.21 ■ **Explaining the difference in performance between science and other subjects[1]**

Results based on students' and school principals' reports, OECD average



1. "Other subjects" refer to reading and mathematics.
2. Time spent learning in addition to the required school schedule, including homework, additional instruction and private study.
Note: Statistically significant correlations are marked in a darker tone (see Annex A3).
Source: OECD, PISA 2015 Database, Table II.2.29.
StatLink http://dx.doi.org/10.1787/888933435632

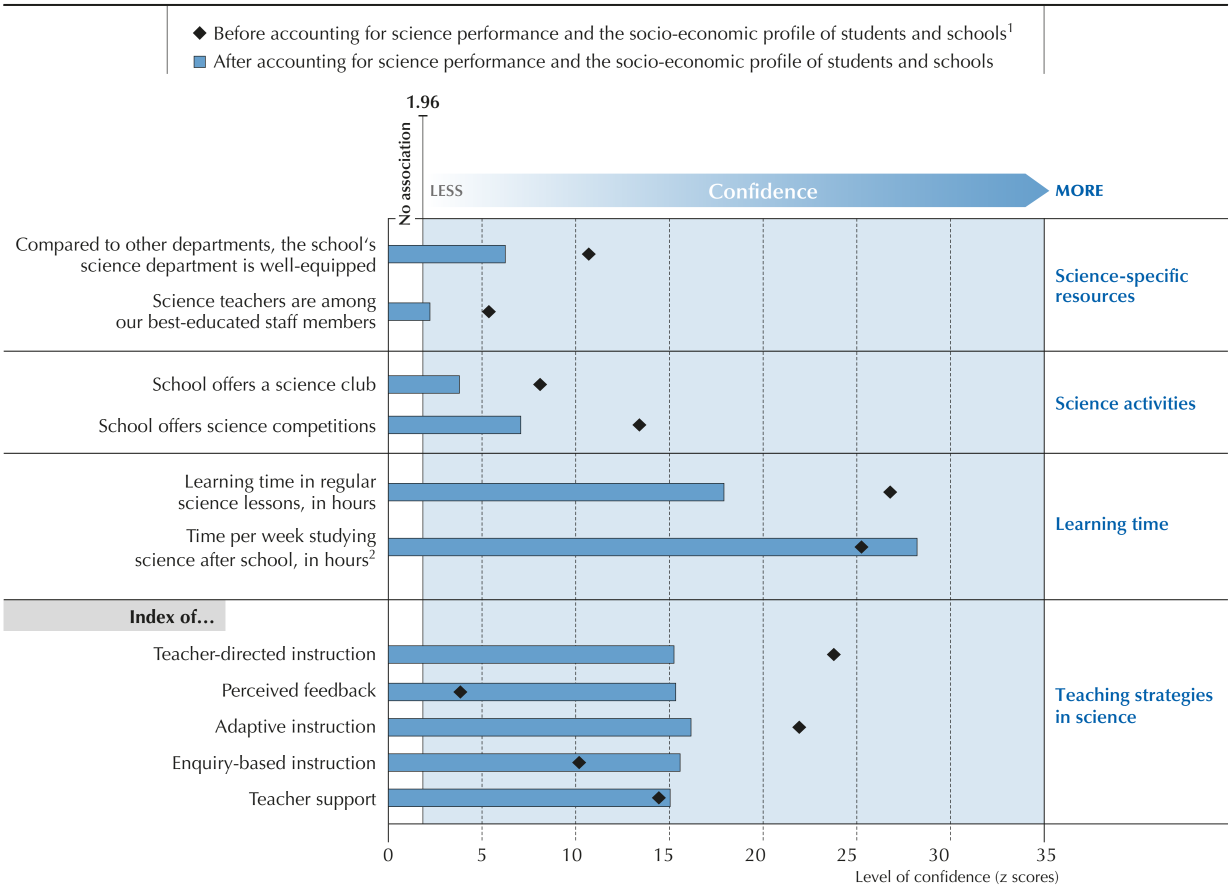
HOW SCIENCE RESOURCES, LEARNING TIME AND TEACHING ARE RELATED TO STUDENTS' EXPECTATIONS OF WORKING IN SCIENCE-RELATED CAREERS

Improving performance in science is not all that matters in science education; encouraging an adequate proportion of students to envision themselves working in science-related occupations in the future is also important in most, if not all, education systems. Figure II.2.22 provides an overview of the factors that are associated with students' expectations of working in science-related occupations when they are 30. As with students' performance in science compared with their performance in other subjects, what is most strongly associated with students' expectations of pursuing a science-related career is how much time they devote to learning science, and how their teachers teach science – even after accounting for students' science performance and the socio-economic profile of students and schools. How well the school's science department is equipped and staffed, relative to other school departments, and what extracurricular activities are offered at school are positively related to students' expectations of a science-related career.

Interestingly, all teaching strategies show a similar positive and strong association with students' expectations of pursuing a science-related career, probably because students become more interested in science when they perceive that teaching, any type of it, happens in their science lessons. The relationship between perceived feedback and expectations of a career in science becomes much stronger after accounting for science performance, presumably because low-performing students tend to be given more feedback from teachers and these students are generally less interested in pursuing science-related careers.

Figure II.2.22 ▪ **Explaining students' expectations of a career in science**

Results based on students' and school principals' reports, OECD average



1. The socio-economic profile is measured by the PISA index of economic, social and cultural status.
2. Time spent learning in addition to the required school schedule, including homework, additional instruction and private study.

Notes: All correlations are statistically significant (see Annex A3).

Z-scores measure the confidence that an association exists between explanatory variables and students' expectations of working in a science-related career. Z-scores above 1.96 mean that the relationship is statistically significant at the 95% confidence level.

Source: OECD, PISA 2015 Database, Table II.2.30.

StatLink http://dx.doi.org/10.1787/888933435641

Notes

1. The index of epistemic beliefs has been standardised to have an average of zero and a standard deviation of one across OECD countries.

2. Students expecting to work in science-related occupations, such as those in the fields of science, engineering, health or information and communication technologies, at the age of 30 were given a value of one; students expecting to work in other occupations, with vague career expectations or with missing or invalid answers were given a value of zero; students who did not reach the questions were excluded from the analysis.

3. Note by Hong Kong: Hong Kong has introduced in 2009 a new secondary curriculum, with Liberal Studies as an interdisciplinary core subject, replacing a system in which students were streamed into more narrow Arts or Science streams. Under the new curriculum, only 3% of students in the modal grade for 15-year-olds are taking all three science subjects (i.e. Physics, Chemistry, Biology), compared to about 37% in the old system; but more students (about 49%) take at least one subject, compared to about 45% in the old system. The learning time for science in senior secondary school is proportional to the number of courses taken.

4. For a description and in-depth analysis of the index of teacher support, please see Chapter 3.

References

Abernathy, T.V. and **R.N. Vineyard** (2001), "Academic competitions in science: What are the rewards for students?" *The Clearing House*, Vol. 74/5, pp. 269-276, http://dx.doi.org/10.1080/00098650109599206.

Backus, L. (2005), "A year without procedures: removing procedures from chemistry labs creates opportunities for student inquiry", *The Science Teacher*, Vol. 72/7, pp. 54-58.

Bellipanni, L.J. and **J.E. Lilly** (1999), "What have researchers been saying about science fairs?" *Science and Children*, Vol. 36/8, p. 46.

Blanchard, S., V. Freiman and **N. Lirrete-Pitre** (2010), "Strategies used by elementary schoolchildren solving robotics-based complex tasks: Innovative potential of technology", *Procedia-Social and Behavioral Sciences*, Vol 2/2, pp. 2851-2857, Elsevier Ltd. London, UK, http://dx.doi.org/10.1016/j.sbspro.2010.03.427.

BonJour, L. (2002), "Internalism and externalism", in P.K. Moser (Ed) *The Oxford Handbook of Epistemology*, Oxford University Press, pp. 234-263, Oxford, UK, http://dx.doi.org/10.1093/0195130057.003.0008.

Brown, P. L. et al. (2006), "College science teachers' views of classroom inquiry", in N.W. Brickhouse (Ed) *Science Education*, Wiley InterScience, Vol. 90/5, pp. 784-802, http://dx.doi.org/10.1002/sce.20151.

Carless, D. (2006), "Differing perceptions in the feedback process", *Studies in Higher Education*, Routledge Vol. 31/2, pp. 219-233, http://dx.doi.org/10.1080/03075070600572132.

Carroll, J. (1963), "A model of school learning", *Teachers College Record*, Vol. 64/8, pp. 723-733, http://dx.doi.org/10.1007/springerreference_302713.

Cheung, D. (2007), "Facilitating chemistry teachers to implement inquiry-based laboratory work", *International Journal of Science and Mathematics Education*, National Taiwan Normal University Vol. 6/1, pp. 107-130, http://dx.doi.org/10.1007/s10763-007-9102-y.

Corter, J. E. et al. (2011), "Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories", *Computers and Education*, Vol. 57/3, pp. 2054-2067, Elsevier Ltd. London, UK, http://dx.doi.org/10.1016/j.compedu.2011.04.009.

Czerniak, C. M. and **A.T. Lumpe** (1996), "Predictors of science fair participation using the theory of planned behaviour", *School Science and Mathematics*, Vol. 96/7, pp. 355-361, http://dx.doi.org/10.1111/j.1949-8594.1996.tb15853.x.

Deci, E.L., R. Koestner, and **R.M. Ryan** (1999), "A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation", *Psychological Bulletin*, Vol. 125/6, pp. 627-668, http://dx.doi.org/10.1037/0033-2909.125.6.627.

Driver, R. (1995), "Constructivist approaches to science teaching", in L. P. Steffe and J. Gale (eds.), Constructivism in Education, Lawrence Erlbaum, Hillsdale, NJ, pp. 385-400.

Furtak, E.M. et al. (2012), "Experimental and quasi-experimental studies of inquiry-based science teaching a meta-analysis", *Review of Educational Research*, Vol. 82/3, pp. 300-329, http://dx.doi.org/10.3102/0034654312457206.

Gallet, C. (1998), "Problem-solving teaching in the chemistry laboratory: Leaving the cooks...", *Journal of Chemical Education*, Vol. 75/1, p. 72, http://dx.doi.org/10.1021/ed075p72.

Galton, M. (2009), "Moving to secondary school: Initial encounters and their effects", in M. Galton (Ed) *Motivating your Secondary Class*, SAGE publications Ltd, New York, NY, Vol. 2/2009, pp. 37-59, http://dx.doi.org/10.4135/9781446221099.n2.

Gardiner, P.G. and **P. Farragher** (1999), "The quantity and quality of biology laboratory work in British Columbia high schools", *School Science and Mathematics*, Vol. 99/4, pp. 197-204, http://dx.doi.org/10.1111/j.1949-8594.1999.tb17474.x.

Goldhaber, D.D. and **D.J. Brewer** (2000), "Does teacher certification matter? High school teacher certification status and student achievement", *Educational Evaluation and Policy Analysis*, vol. 22/2, pp. 129-145, http://dx.doi.org/10.3102/01623737022002129.

Gunstone, R.F. and **A.B Champagne** (1990), "Promoting conceptual change in the laboratory", *The Student Laboratory and the Science Curriculum*, pp. 159-182.

Hanushek, E.A., M. Piopiunik and **S. Wiederhold** (2014), "The value of smarter teachers: International evidence on teacher cognitive skills and student performance", no. w20727, National Bureau of Economic Research, Cambridge, MA, http://dx.doi.org/10.3386/w20727.

Harrison, M. (2012), "Jobs and growth: The importance of engineering skills to the UK economy", *Royal Academy of Engineering Econometrics of Engineering Skills Project,* Royal Academy of Engineering, London.

Hattie, J.A.C. (2009), "*Visible Learning: A Synthesis of 800+ Meta-analyses on Achievement*", Routledge, Abingdon, http://dx.doi.org/10.1007/s11159-011-9198-8.

Hattie, J. and **H. Timperley** (2007), "The power of feedback", *Review of Educational Research*, Vol. 77/1, pp. 81-112, http://dx.doi.org/10.3102/003465430298487.

Hodson, D. (1993), "Re-thinking old ways: Towards a more critical approach to practical work in school science", Studies in Science Education, Vol. 22, pp. 85-142, http://dx.doi.org/10.1080/03057269308560022.

Hofer, B.K. and **P.R. Pintrich** (1997), "The development of epistemic theories: Beliefs about knowledge and knowing and their relation to learning", *Review of Educational Research*, Vol. 67/1, pp. 88-140, http://dx.doi.org/10.3102/00346543067001088.

Höffler, T.N., V. Bonin and **I. Parchmann** (2016), "Science vs. sports: Motivation and self-concepts of participants in different school competitions", *International Journal of Science and Mathematics Education*, pp. 1-20, http://dx.doi.org/10.1007/s10763-016-9717-y.

Hofstein, A. and **V.N. Lunetta** (2004), "The laboratory in science education: Foundations for the twenty-first century", *Science Education*, Vol. 88/1, pp. 28-54, http://dx.doi.org/10.1002/sce.10106.

Huler, S. (1991), "Nurturing science's young elite: Westinghouse talent search", *Scientist*, Vol. 5/8, pp. 20-22.

Husen, T. (ed.) (1967), *International Study of Achievement in Mathematics: A Comparison of Twelve Countries* (Vol. I), Wiley and Sons, New York, NY.

Langdon, D. et al. (2011), "STEM: Good jobs now and for the future", *ESA Issue Brief*, Vol. 03/11, US Department of Commerce, Washington, D.C.

Lawson, A.E., K. Costenson and **R. Cisneros** (1986), "A summary of research in science education-1984", *Science Education*, Vol. 70/3, pp. 189-346, http://dx.doi.org/10.1002/sce.3730700302.

Lipko-Speed, A., J. Dunlosky and **K.A. Rawson** (2014), "Does testing with feedback help grade-school children learn key concepts in science?" *Journal of Applied Research in Memory and Cognition*, Elsevier Ltd, London, UK Vol. 3/3, pp. 171-176, http://dx.doi.org/10.1016/j.jarmac.2014.04.002.

Minner, D.D., A.J. Levy and **J. Century** (2010), "Inquiry-based science instruction: What is it and does it matter? Results from a research synthesis years 1984 to 2002", *Journal of Research in Science Teaching*, Vol. 47/4, pp. 474-496, http://dx.doi.org/10.1002/tea.20347.

OECD (2016), Ten Questions for Mathematics Teachers ... and how PISA can help answer them, PISA, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264265387-en.

Palardy, G. J. and **R.W. Rumberger** (2008), "Teacher effectiveness in first grade: The importance of background qualifications, attitudes, and instructional practices for student learning", *Educational Evaluation and Policy Analysis*, Vol. 30/2, pp. 111-140, http://dx.doi.org/10.3102/0162373708317680.

Spillane, J.P. et al. (2001), "Urban school leadership for elementary science instruction: Identifying and activating resources in an undervalued school subject", *Journal of Research in Science Teaching*, Vol. 38/8, pp. 918-940, http://dx.doi.org/10.1002/tea.1039.

Thomas, G. E. (1986), "Cultivating the interest of women and minorities in high school mathematics and science", *Science Education*, Wiley & Sons, New York, NY, Vol. 70/1, pp. 31-43, http://dx.doi.org/10.1002/sce.3730700105.

Tobin, K. (1990), "Research on science laboratory activities: In pursuit of better questions and answers to improve learning", *School Science and Mathematics*, Vol. 90/5, pp. 403-418, http://dx.doi.org/10.1111/j.1949-8594.1990.tb17229.x.

Tyack, D.B. and **L. Cuban** (1995), *Tinkering Toward Utopia*, Harvard University Press, Cambridge, MA.

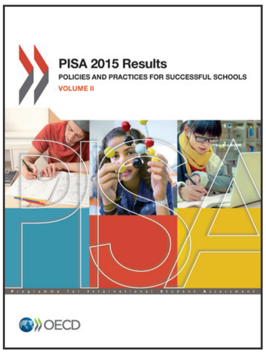
Vedder-Weiss, D. and **D. Fortus** (2011), "Adolescents' declining motivation to learn science: Inevitable or not?" *Journal of Research in Science Teaching*, Vol. 48/2, pp. 199-216, http://dx.doi.org/10.1002/tea.20398.

Woolnough, B. E. (1991), "Setting the scene", in B. E. Woolnough (ed.), Practical Science, Open University Press, Milton Keynes, pp. 3-9.

Yaakobi, D. (1981), "Some differences in modes of use of an environmental education programme by school teachers and community leaders", *European Journal of Science Education*, Vol. 3/1, pp. 69-76, http://dx.doi.org/10.1080/0140528810030107.

Yung, B. H. W. (2001), "Three views of fairness in a school-based assessment scheme of practical work in biology", *International Journal of Science Education*, Vol. 23/10, pp. 985-1005, http://dx.doi.org/10.1080/09500690010017129.

Zacharia, Z. C. and **G. Olympiou** (2011), "Physical versus virtual manipulative experimentation in physics learning", *Learning and Instruction*, Elsevier Ltd. London, UK, Vol. 21/3, pp. 317-331, http://dx.doi.org/10.1016/j.learninstruc.2010.03.001.



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