2

Integrating Information and Communication Technology in Teaching and Learning

This chapter discusses how education systems and schools are integrating information and communication technology (ICT) into students' learning experiences, and examines trends since 2009. It provides an overview of country differences in schools' ICT resources and how these are related to computer use; and it shows how the use of ICT in school not only depends on its availability, but on policies related to teachers and curricula.

With computers and the Internet increasingly part of the environment in which young adults grow and learn, schools and education systems are urged to reap the educational benefits of information and communication technology (ICT). Co-ordinated ICT policies often exist at the school, district or national level. They help schools and teachers to keep abreast of the constant flow of technological novelty, and to manage the change and disruption that some new tools may introduce.

Education policies that aim to embed ICT more deeply into schools and teachers' practices are often justified on one of several grounds. First, as a tool, ICT devices and the Internet hold the promise of enhancing the (traditional) learning experiences of children and adolescents, and perhaps of acting as a catalyst for wider change where such change is desired. Second, the widespread presence of ICT in society, used for everyday work and leisure activities, and the increasing number of goods and services whose production relies on ICT, create a demand for digital competencies, which are, arguably, best learned in context. Third, while learning with and about ICT may well take place outside of school, initial education can play a key role in ensuring that everyone can use these technologies and benefit from them, bridging the divide between rich and poor. Finally, school ICT policies may be based on the desire to reduce administrative and other costs. Where teacher shortages exist or can be expected, ICT policies may also complement other actions taken to attract and retain teachers in the profession.

What the data tell us

- On average, seven out of ten students use computers at school – a proportion unchanged since 2009. Among these students, the frequency of computer use increased in most countries during the period.
- The countries with the greatest integration of ICT in schools are Australia, Denmark, the Netherlands and Norway. Rapid increases in the share of students doing school work on computers can often be related to large-scale laptop-acquisition programmes, such as those observed in Australia, Chile, Greece, New Zealand, Sweden and Uruguay.
- The level of ICT use in mathematics lessons is related to both the content and the quality of instruction. Countries and economies where students are more exposed to real-world applications of mathematics tend to use computers more. There is also a specific association between mathematics teachers' use of student-oriented practices, such as individualised instruction, group work and project-based learning, and their willingness and ability to integrate ICT into mathematics lessons.

Information and communication technologies can support and enhance learning. With access to computers and the Internet, students can search for information and acquire new knowledge beyond what is available through teachers and textbooks. ICT also provide students with new ways to practice their skills – e.g. maintaining a personal webpage or online publication, programming computers, talking and listening to native speakers when learning a second language, and/or preparing a multimedia presentation, whether alone or as part of a remotely connected team. ICT devices bring together traditionally separated education media (books, writing, audio recordings, video recordings, databases, games, etc.), thus extending or integrating the range of time and places where learning can take place (Livingstone, 2011).

The widespread presence of ICT in everyday lives also creates a need for specific skills and literacies. At the very least, education can raise awareness in children and their families about the risks that they face online and how to avoid them (OECD, 2012). But as a dynamic and changing technology that requires its users to update their knowledge and skills frequently, ICT also invites education to rethink the content and methods of teaching and learning. Users of ICT – as we all are today – often must adjust to a new device or software or to new functions of their existing devices and applications. As a result, ICT users must learn, and unlearn, at a rapid pace. Only those who can direct this process of learning themselves, solving unfamiliar problems as they arise, fully reap the benefits of a technology-rich world.

More specifically, education may prepare young people for working in the sectors where new jobs are expected to be created in the coming years. Today, ICT is used across all sectors of the economy, and many of the sectors with high levels of ICT use, such as financial services and health, are also those that have increased their share of employment over the past several decades (OECD, 2013a). Other sectors of the economy that were shielded from international competition, such as retail trade or news dissemination, have been transformed by the rise of the corresponding online services. And whatever their desired jobs are, when today's students leave school or university, they will most likely search and apply for jobs on line. As a consequence, a high level of familiarity with ICT among the workforce can be a competitive advantage for countries in the new service economy.

This chapter investigates how education systems and schools are integrating ICT into students' learning experiences, and examines changes since 2009. It provides an overview of country differences in schools' ICT resources and how these are related to computer use. It shows that the use of ICT clearly depends on the availability of adequate infrastructure – equipping schools with more and better ICT resources – but is also related to the wider context shaped by teacher and curricular policies.

STUDENTS' USE OF COMPUTERS AT SCHOOL

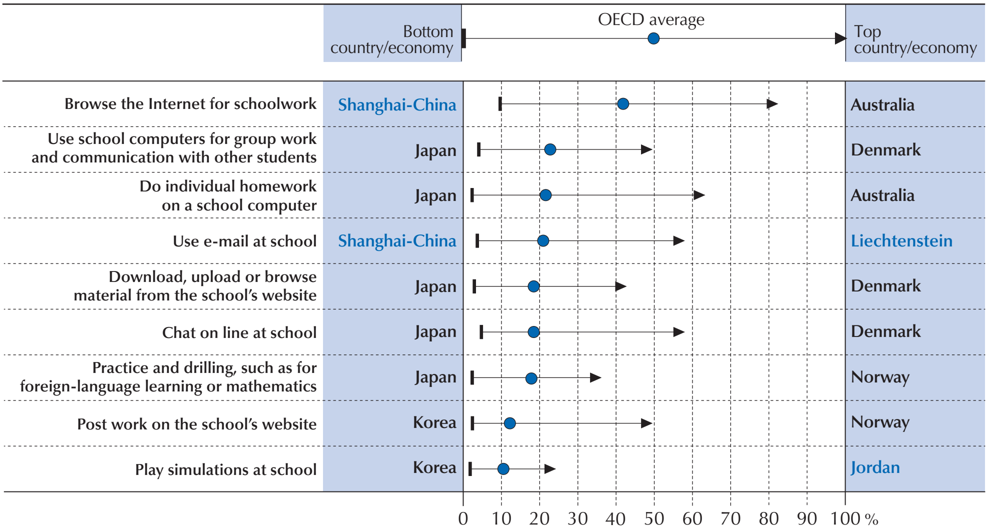
A basic indicator of how integrated ICT devices are in teaching and learning is the share of students who use computers at school, particularly if this use is regular and occurs at least once a week.

In PISA 2012, as in PISA 2009, students reported whether they use computers at school, and how frequently they engaged in nine activities using computers at school: chat on line; use e-mail; browse the Internet for schoolwork; download, upload or browse material from the school's website; post work on the school's website; play simulations at school; practice and repeat lessons, such as for learning a foreign language or mathematics; do individual homework on a school computer; and use school computers for group work and to communicate with other students. On average across OECD countries, 72% of students reported using desktop, laptop or tablet computers at school (by comparison, 93% of students reported that they use computers at home). As in 2009, the task most frequently performed on school computers was browsing the Internet for schoolwork, with 42% of students, on average, doing so once a week or more often. The activity performed the least frequently was playing simulations at school (11% of students on average across OECD countries) (Figure 2.1 and Table 2.3).

■ Figure 2.1 ■

Use of ICT at school

Percentage of students who reported engaging in each activity at least once a week

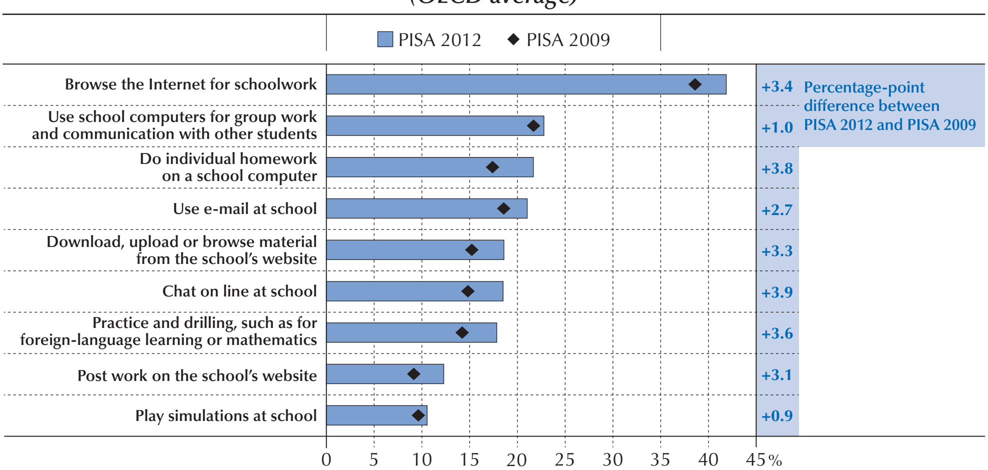


Source: OECD, PISA 2012 Database, Table 2.1.
StatLink http://dx.doi.org/10.1787/888933252687

■ Figure 2.2 ■

Change between 2009 and 2012 in ICT use at school

Percentage of students who reported engaging in each activity at least once a week (OECD average)



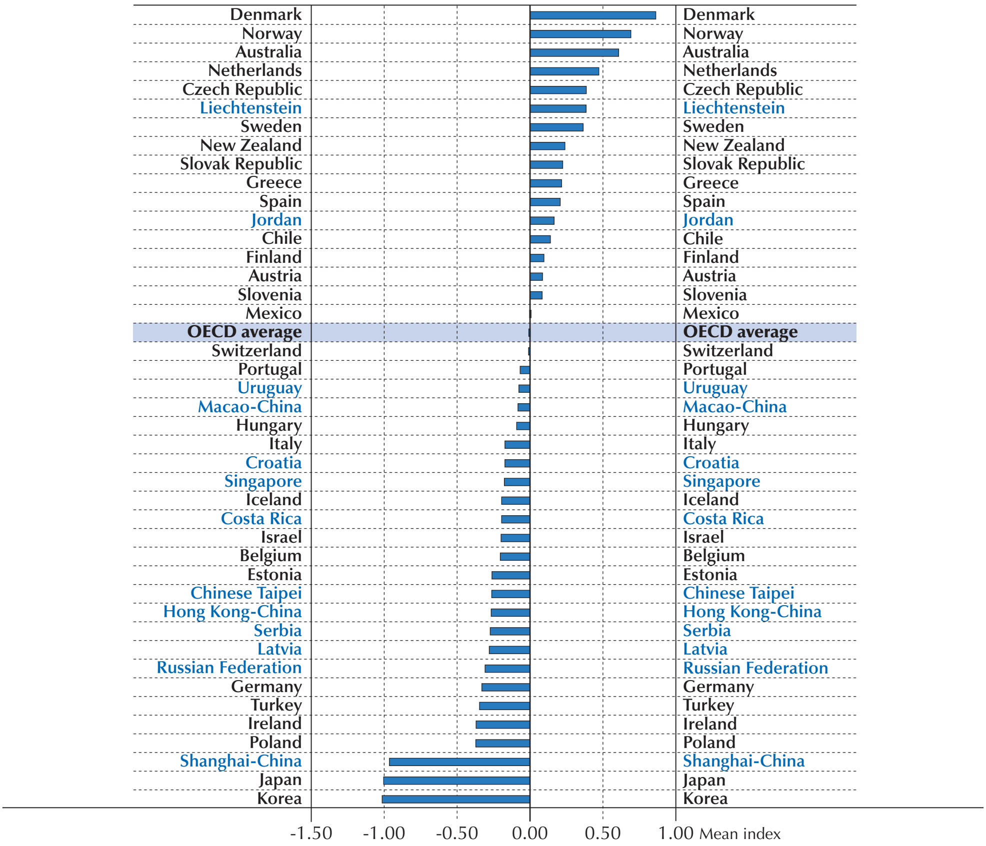
Notes: PISA 2012 and PISA 2009 values are based on all OECD countries with available data. The difference between 2012 and 2009 is based on OECD countries with data in both waves.
All reported differences between PISA 2012 and PISA 2009 are statistically significant.
Source: OECD, PISA 2012 Database, Table 2.1.
StatLink http://dx.doi.org/10.1787/888933252698

While the average share of students who use computers at school did not increase much over the period (in 2009, 71% of students reported using computers at school, only 1 percentage point less than in 2012 – see Figure 2.4), the type and intensity of use did change over the period. Indeed, across all the school-related activities performed on computers listed in PISA 2009 and PISA 2012, the average share of students across OECD countries who frequently engage in these activities increased significantly over the three-year period (Figure 2.2).

Perhaps reflecting the increased availability of laptop and other mobile computers at school (see Table 2.9), the use of computers for activities in which students work individually (online chats, practice and drilling, and doing individual homework) increased the most among all the listed activities between 2009 and 2012. The share of students who engaged in each of these activities at least once a week grew by about 4 percentage points during the period (Figure 2.2).

■ Figure 2.3 ■

Index of ICT use at school



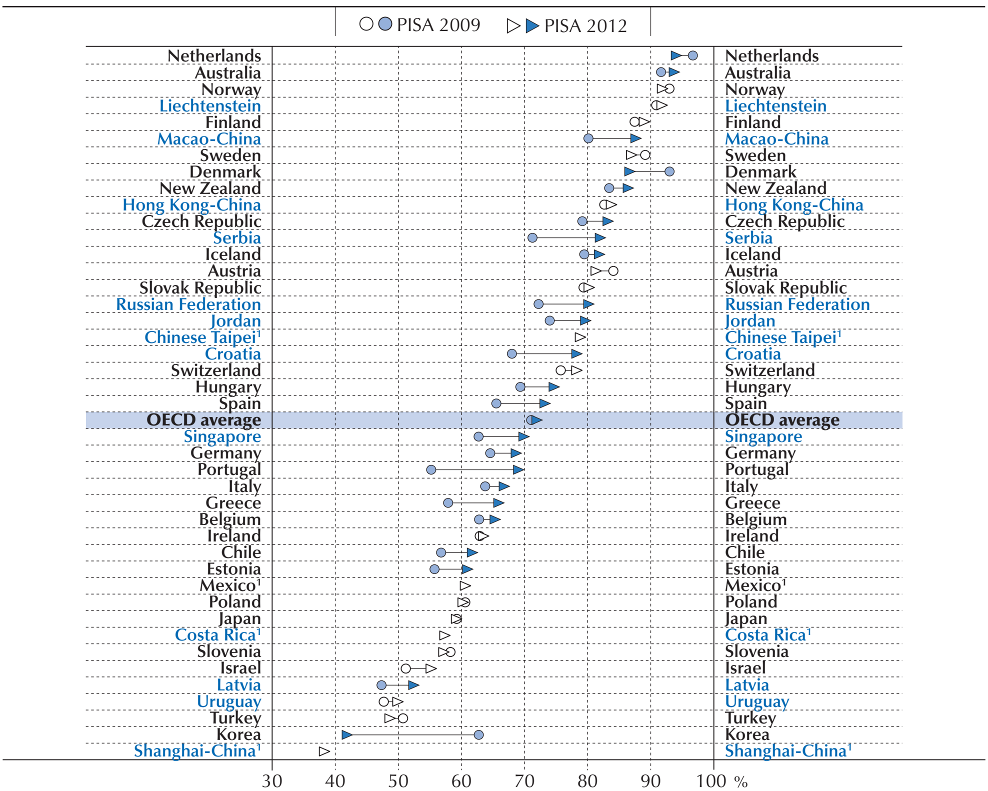
Countries and economies are ranked in descending order of the mean index of ICT use at school.
Source: OECD, PISA 2012 Database, Table 2.2.
StatLink http://dx.doi.org/10.1787/888933252700

When all nine activities are summarised in the *index of ICT use at school*,[1] the countries with the highest mean values are Australia, Denmark, the Netherlands and Norway. In contrast, students in Japan, Korea and Shanghai-China make significantly less use of computers at school than students in any other country/economy, according to students' reports (Figure 2.3).[2]

When students report infrequent use of computers at school, it should not be assumed that ICT equipment is not used at all. Students in Shanghai-China, for instance, use computers during mathematics lessons the least (see Figure 2.7). However, they also report, more often than students in OECD countries do, that teachers use ICT equipment during lessons (perhaps projectors and smartboards). Such teacher-centred approaches to integrating ICT into education are only imperfectly covered by PISA measures. Similarly, the use of smartphones at school may not be captured by the questions referring to "computer" use.

■ Figure 2.4 ■

Change between 2009 and 2012 in the share of students using computers at school



1. PISA 2009 data are missing for Costa Rica, Mexico, Shanghai-China and Chinese Taipei.
Note: White symbols indicate differences between PISA 2009 and PISA 2012 that are not statistically significant.
Countries and economies are ranked in descending order of the percentage of students using computers at school in 2012.
Source: OECD, PISA 2012 Database, Table 2.3.
StatLink http://dx.doi.org/10.1787/888933252710

Still, not all trends point towards a greater use of computers at school.[3] When the shares of students using computers at school are compared across PISA cycles, a large decline (-21 percentage points) is observed in Korea between 2009 and 2012. In 2012, only 42% of students in Korea reported that they use computers at school – the second smallest proportion among the 42 countries/economies surveyed, after Shanghai-China (38%). In Denmark, where the share of students who use computers at school was second only to the Netherlands in 2009, this share shrank by 6 percentage points to below 90% in 2012 (Figure 2.4 and Table 2.3).

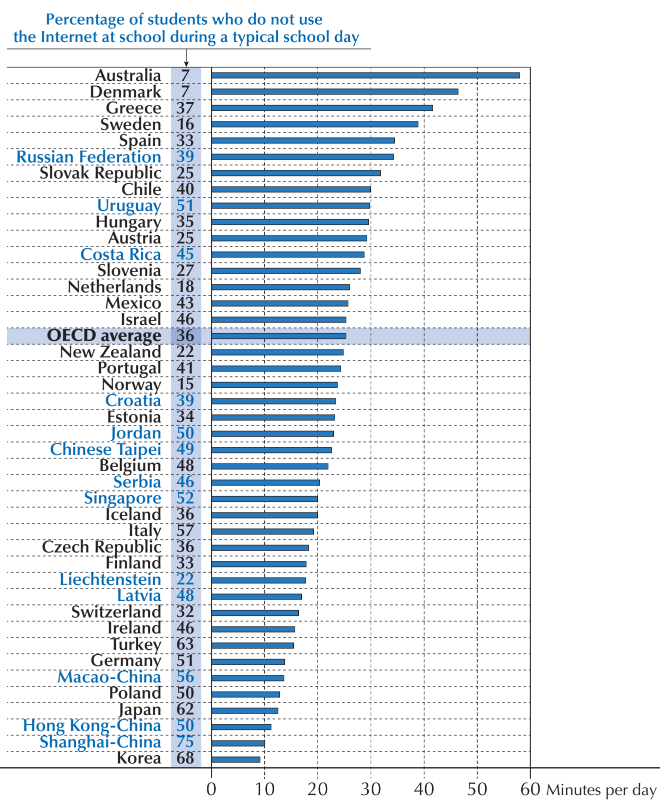
Internet use at school

Students' self-reports show that, on average across OECD countries, students typically spend at least 25 minutes on line each day at school. In Australia, the time spent on line at school is more than twice the average (58 minutes); in Denmark students spend an average of 46 minutes on line per day at school, in Greece they spend 42 minutes, and in Sweden 39 minutes (Figure 2.5).

■ Figure 2.5 ■

Time spent on line at school

Average time students spend using the Internet at school (lower bound)



Countries and economies are ranked in descending order of the average time students spend using the Internet at school.

Source: OECD, PISA 2012 Database, Table 1.5c.

StatLink http://dx.doi.org/10.1787/888933252720

In 11 countries and economies, namely Germany, Italy, Japan, Jordan, Korea, Macao-China, Poland, Shanghai-China, Singapore, Turkey and Uruguay, on a typical school day, a majority of students do not use the Internet at school (Figure 2.5).

Computer use during mathematics instruction

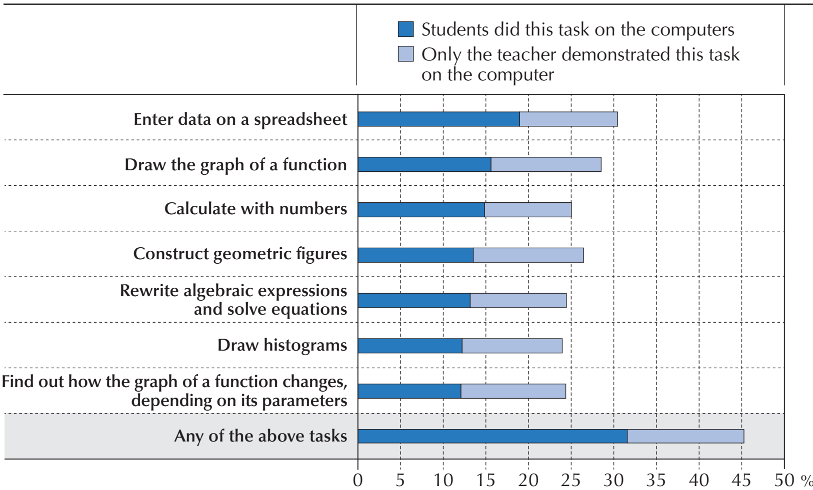
PISA 2009 showed that computers were used less frequently during classroom lessons in mathematics than in either language or science classes, with only about 15% of students using computers at least once a week in mathematics classes, on average across OECD countries (OECD, 2011, Figure VI.5.21).

PISA 2012 took a closer look at whether and how students use computers during mathematics lessons. Students were given a list of seven possible mathematics tasks on computers and were asked to report whether, during the month preceding the survey, they (or their classmates) had performed any of those tasks during mathematics lessons, whether teachers demonstrated the task, or whether they had not encountered the task at all. The tasks included: drawing the graph of a function; calculating with numbers; constructing geometric figures; entering data in a spreadsheet; rewriting algebraic expressions and solving equations; drawing histograms; and finding out how the graph of a function changes, depending on its parameters.

■ Figure 2.6 ■

Use of computers during mathematics lessons

Percentage of students who reported that a computer was used in mathematics lessons in the month prior to the PISA test, by task (OECD average)



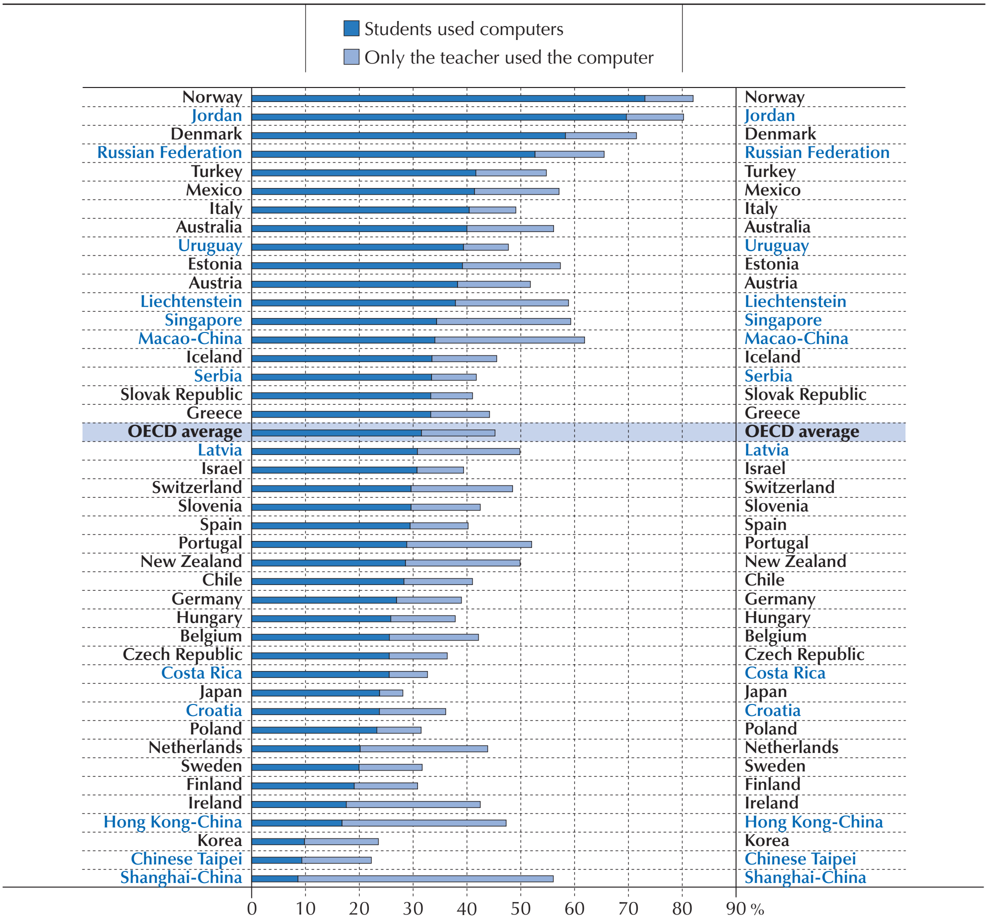
Source: OECD, PISA 2012 Database, Table 2.5.
StatLink http://dx.doi.org/10.1787/888933252733

On average across OECD countries, only a minority of students saw any of these tasks performed in their mathematics class during the month preceding the PISA test. This is consistent with the finding that computers are infrequently used during mathematics instruction. For 14% of students, on average, only teachers demonstrated the use of computers; 32% of students reported that they, or their classmates, did at least one of the tasks. However, in some countries, computer use during mathematics lessons was much more common. More than two out of three students in Norway (82% of students), Jordan (80%) and Denmark (71%) saw at least one of these tasks demonstrated by their teachers; often, the students themselves performed the task on computer (Figures 2.6 and 2.7).

■ Figure 2.7 ■

Students and teachers using computers during mathematics lessons

Percentage of students who reported that a computer was used in mathematics lessons in the month prior to the PISA test



Note: This figure shows the percentage of students who reported that a computer was used in mathematics lessons during the month prior to the PISA test for at least one of seven mathematics tasks (see Figure 2.6 for the list of tasks).
Countries and economies are ranked in descending order of the percentage of students who used computers during mathematics lessons.
Source: OECD, PISA 2012 Database, Table 2.5.
StatLink http://dx.doi.org/10.1787/888933252749

Some 19% of students, on average across OECD countries, reported that they had entered data on a spreadsheet during mathematics lessons in the month prior to the PISA test; in Norway, over 67% of students so reported. The second most common activity, drawing the graph of a function, was performed by16% of students on average, and only 31% of Norwegian students (Figure 2.6 and Table 2.5).

Finland, Japan, Korea, Poland and Chinese Taipei, all high-performing countries/economies in PISA, show the least frequent use of computers in mathematics lessons; and in Shanghai-China, students reported that teachers demonstrate certain tasks on computers relatively frequently, but the share of students who perform any of the tasks themselves is the smallest among all countries and economies (Figure 2.7). The relationship between computer use and performance is further explored in Chapter 6.

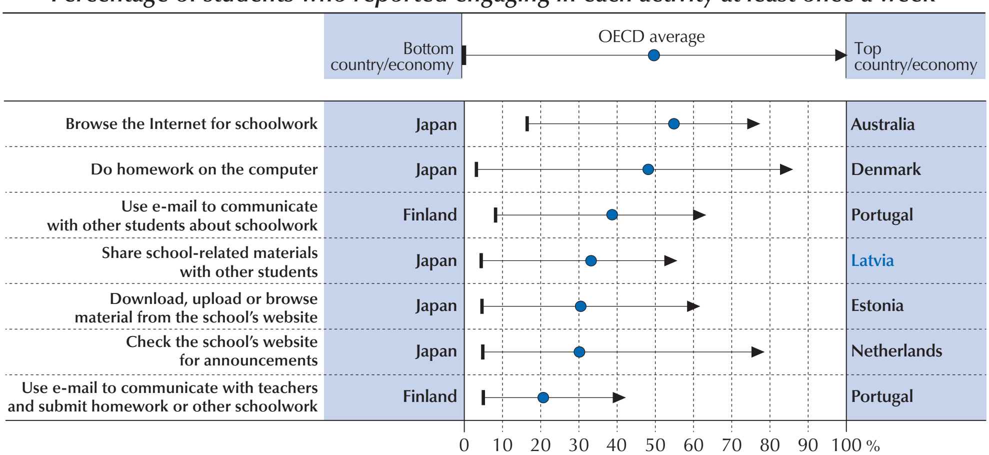
Use of home computers for schoolwork

With ICT devices readily available at home and within the community, the school day can be expanded beyond the physical classroom. Learning activities can be offered on line and off line, on site (at school) and off site (outside of school). In PISA 2012, students were asked whether they use computers for seven school-related tasks (six of which were also included in the PISA 2009 questionnaire) outside of school. An index was generated to summarise schoolwork-related activities that take place outside of school.

■ Figure 2.8 ■

Use of ICT outside of school for schoolwork

Percentage of students who reported engaging in each activity at least once a week



Source: OECD, PISA 2012 Database, Table 2.7.
StatLink http://dx.doi.org/10.1787/888933252758

In general, students more frequently use their home computers (or other computers outside of school) for schoolwork than they use school computers. For instance, while 42% of students browse the Internet for schoolwork at least once a week at school, 55% of students do so outside of school, on average across OECD countries (Tables 2.1 and 2.7). Still, only a minority of students engages in school-related activities on computers at least once a week, except for browsing the Internet to help with schoolwork (55% of students). On average across OECD countries only 48% of students do homework on a computer, 38% use e-mail to communicate with other students about schoolwork, and 33% share school-related materials with other students via computer. The least common activities are those that require a corresponding online presence by the school or the teacher. For example, 30% of students check their school's website for announcements, 30% download, upload or browse material from the school's website, and only 21% use e-mail to communicate with teachers or submit schoolwork (Figure 2.8).

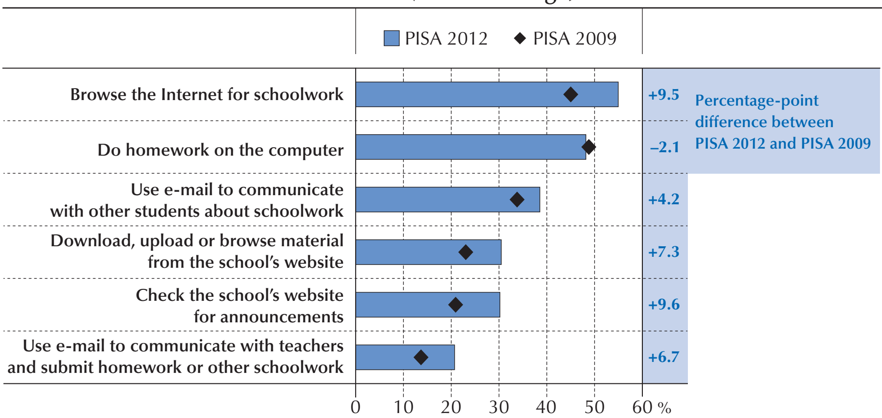
The share of students who regularly perform tasks that require an online presence of teachers and school leaders grew faster than the share of students who perform the remaining school-related activities. Three out of ten students in 2012 check the school website for announcements at least once a week – 10% more, on average, than in 2009 (Figure 2.9). Overall, however, these tasks are still relatively infrequent.

When all activities are combined to form an *index of ICT use outside of school for schoolwork*, the highest values on the index are observed in Denmark, Estonia, the Netherlands and Uruguay. More than 70% of students in Denmark and Uruguay browse the Internet for schoolwork and do homework on computers at least once a week. Meanwhile, a large majority of students in Estonia and the Netherlands regularly checks the school's website for announcements or uses a computer to download, upload or browse materials from the school's website (Figure 2.10 and Table 2.7).

■ Figure 2.9 ■

Change between 2009 and 2012 in ICT use outside of school for schoolwork

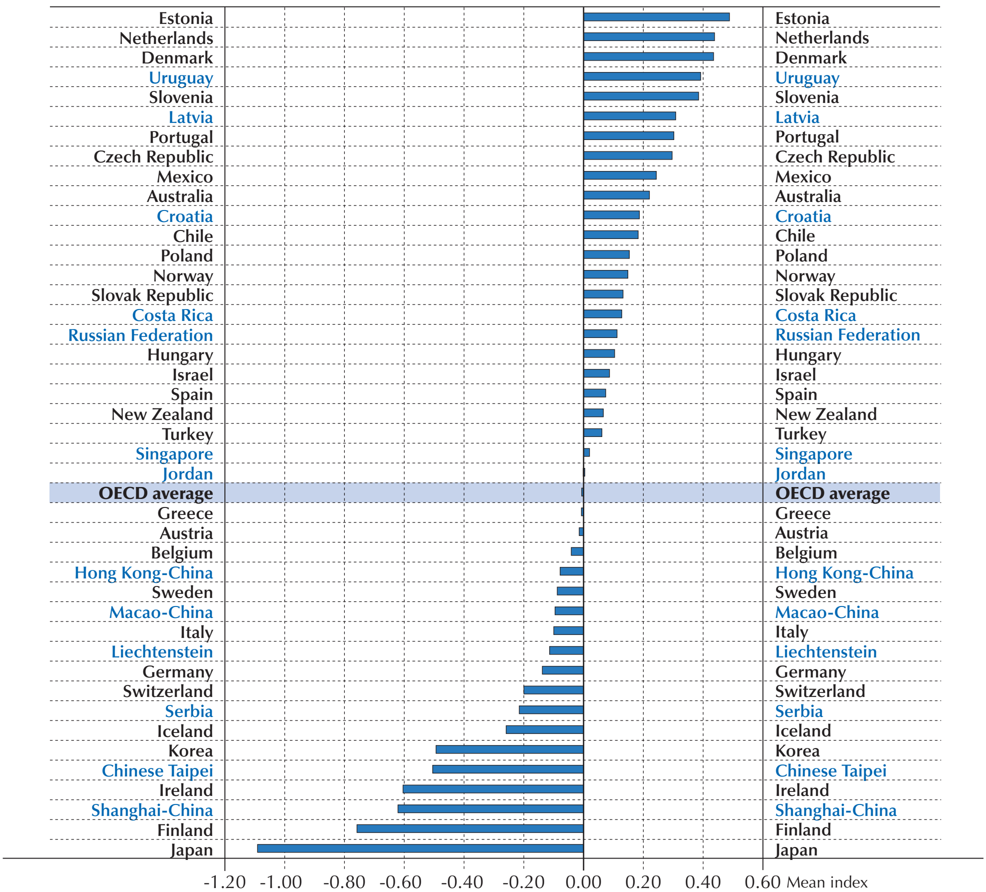
Percentage of students who reported engaging in each activity at least once a week (OECD average)



Notes: PISA 2012 and PISA 2009 values are based on all OECD countries with available data. The difference between 2012 and 2009 is based on OECD countries with data in both waves.
All reported differences between PISA 2012 and PISA 2009 are statistically significant.
Source: OECD, PISA 2012 Database, Table 2.7.
StatLink http://dx.doi.org/10.1787/888933252765

■ Figure 2.10 ■

Index of ICT use outside of school for schoolwork



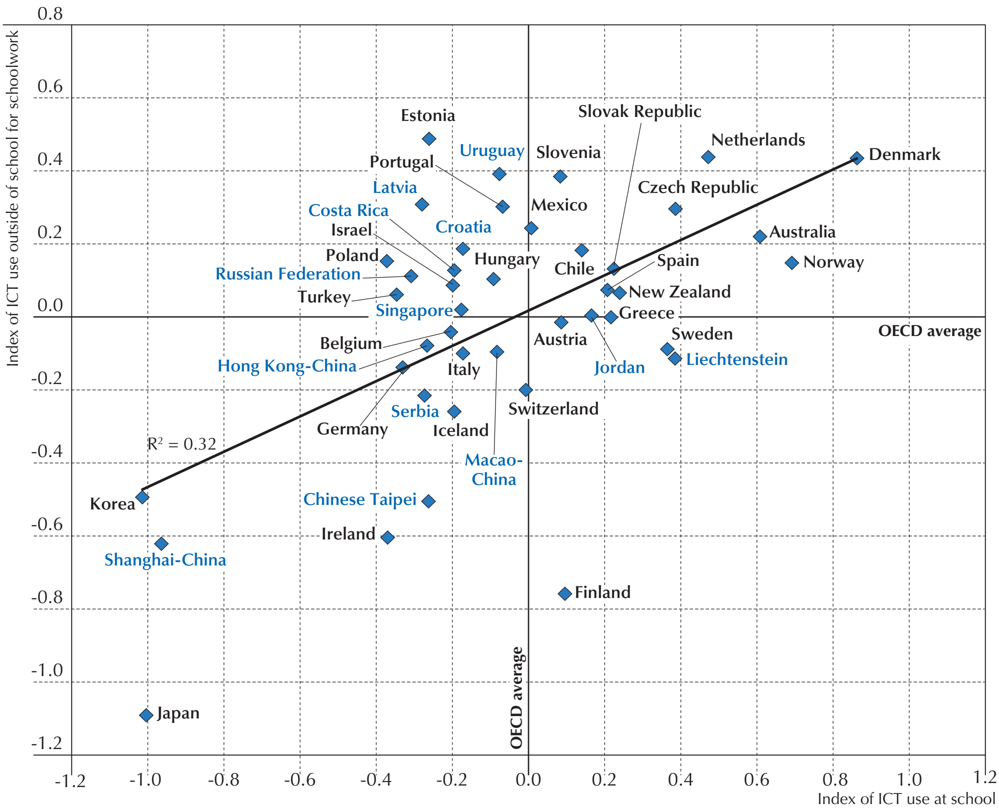
Countries and economies are ranked in descending order of the mean index of ICT use outside of school for schoolwork.
Source: OECD, PISA 2012 Database, Table 2.8.
StatLink http://dx.doi.org/10.1787/888933252770

Finland and Japan are the two countries where students make the least use of computers outside of school for schoolwork. Some of this may be related to homework policies: students in Finland and Japan are typically assigned little, if any, homework (OECD, 2013b, Figure IV.3.10).

As can be expected, there is a positive relationship between the extent to which students use ICT at school for schoolwork and the extent to which they use other ICT resources outside of school for schoolwork. However, in several countries where ICT use at school is below average, ICT use outside of school – for school-related reasons – is above average, most notably in Croatia, Estonia, Latvia, Portugal and Uruguay (Figure 2.11).

■ Figure 2.11 ■

Relationship between use of ICT outside of school for schoolwork and use of ICT at school



Source: OECD, PISA 2012 Database, Tables 2.2 and 2.8.
StatLink http://dx.doi.org/10.1787/888933252787

DRIVERS AND BARRIERS TO INTEGRATING ICT INTO TEACHING AND LEARNING

Previous sections described large differences between countries in the extent to which 15-year-olds use computers in schools. What drives these differences?

The absence or difficulty of accessing ICT devices and connecting them to the Internet is certainly a barrier to integrating ICT in teaching and learning. Differences in the devices available to schools indicate either a deliberate choice not to invest in the integration of ICT in teaching and learning, or a lack of sufficient resources to do so.

At the same time, not all between- and within-country differences in the use of ICT devices at school can be traced back to disparities in their availability. Other variables influence how willing and ready schools and teachers are to integrate new devices into their practices.

Indeed, to harness the potential of ICT, teachers and industry must create and develop new educational resources (software, textbooks, lesson plans, etc.). They may find encouragement and support to do so in changes in related education policies, including curricula, student- and teacher-assessment frameworks, initial teacher training (Tondeur et al., 2012) and professional development activities for teachers, as well as in school practices that support collaboration and encourage teachers to take risks and share lessons learned (Little, 1982; Frost and Durrant, 2003; Harris, 2005; Horn and Little, 2010; Resnick et al., 2010; Avvisati et al., 2013).

While PISA data cannot be used to characterise initial teacher training, professional development, and teachers' working conditions,[4] it can illustrate how ICT use at school is related to other drivers of/barriers to innovation, such as variations in infrastructure and curricula.

The school ICT infrastructure

As part of the ICT familiarity questionnaire, students were asked if there are computers available for them to use at school. On average across OECD countries, 92% of students reported that they have access to a computer (in 2012, computers include desktop, laptop and tablet computers). This proportion declined by 0.6 percentage points, on average across OECD countries with comparable data, between 2009 and 2012. The largest declines in access to computers at school were observed in Slovenia (by 8 percentage points), and in Belgium, Japan and Korea (by 5 percentage points). In contrast, in Greece, Jordan, Portugal, Serbia, Spain, Turkey and Uruguay, more students had access to computers in 2012 than in 2009. Among this group of countries, Portugal had the highest rate of access to school computers in 2012 (98%); only Australia, Denmark, Hong Kong-China, Liechtenstein, the Netherlands, New Zealand, Norway and Singapore had similar (or sometimes higher) rates in 2012 (Figure 2.12).

Similarly, in 2012, nine in ten students, on average, reported that they have an Internet connection available at school – a slightly smaller proportion than in 2009. Between 2009 and 2012, the proportion of students with access to the Internet at school declined by two percentage points, on average across OECD countries. Still, in all countries more than 70% of students reported that they have access to an Internet connection at school (Figure 2.13).

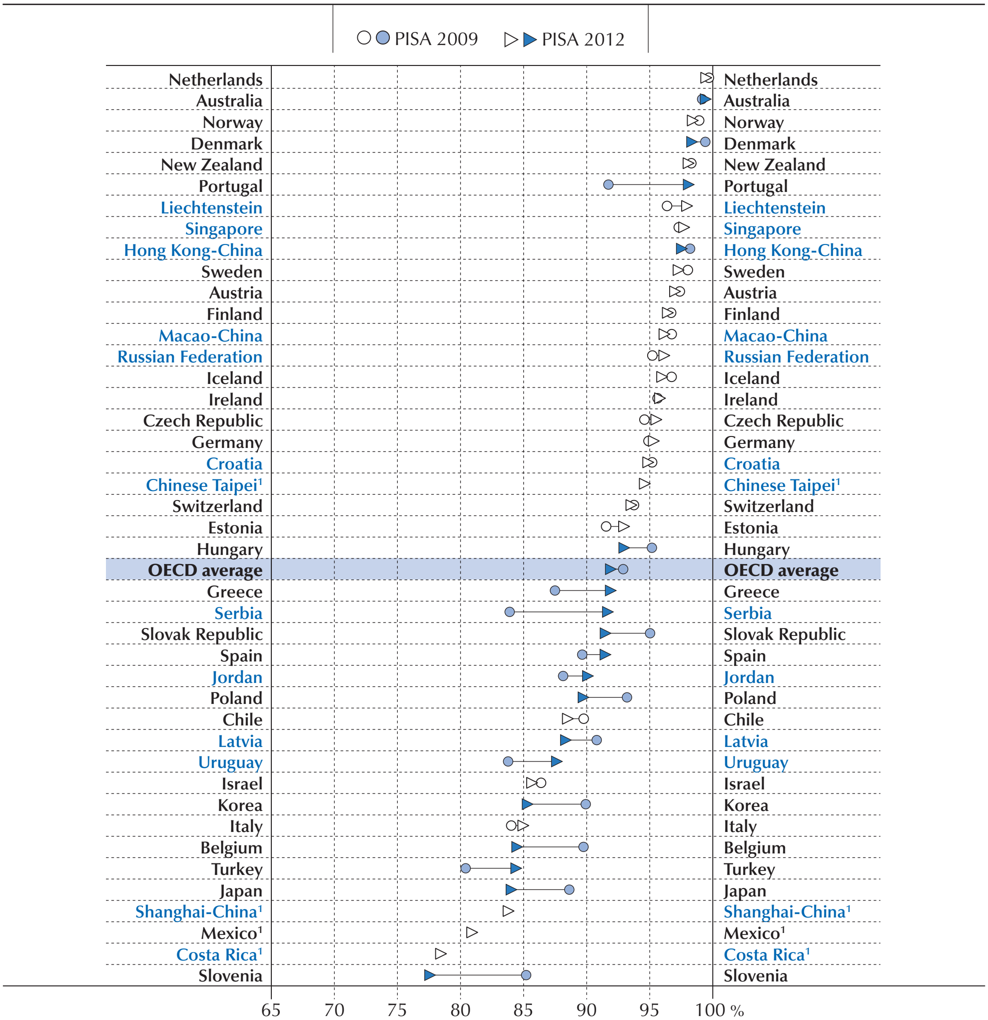
Some of the apparent declines in access may be due to changes in the reference frame of students. Given the rapid improvements in broadband infrastructure between 2009 and 2012 (see Chapter 1), it is possible that, when answering the question in 2012, some students may not have considered slow or difficult-to-access Internet connections in the same way as their peers did in 2009.

Indeed, principals' reports about their schools' ICT resources paint a somewhat different picture. The number of computers in schools did not change significantly across OECD countries, on average, but the share of school computers connected to the Internet increased between 2009 and 2012 (Figures 2.14 and 2.15)

In 2012 as in 2009 there were between four and five students to every school computer, on average across the OECD. The number of computers available to 15-year-old students increased in 17 countries/economies (as reflected in lower student/computer ratios), and decreased in six – most notably in Turkey. At the same time, the share of school computers that were not connected to the Internet decreased, from about 4% to less than 3%, on average.

■ Figure 2.12 ■

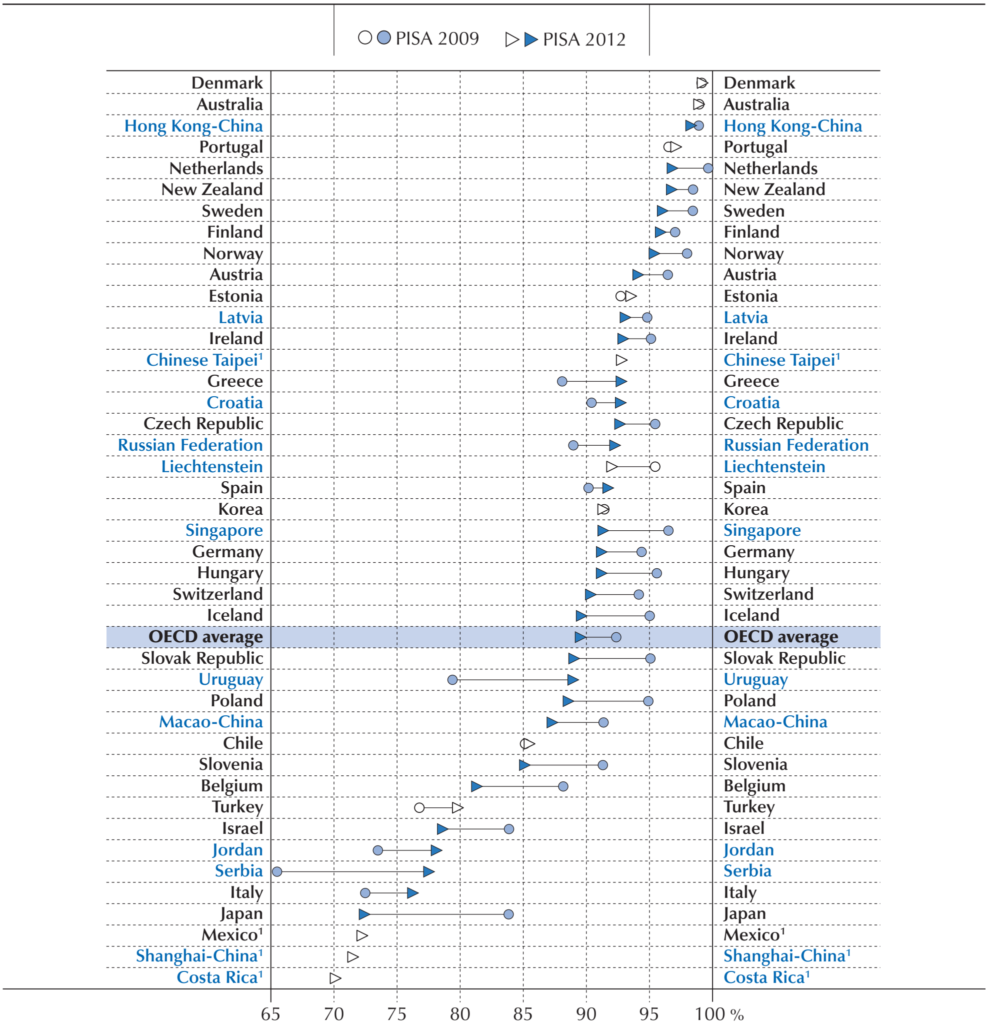
Change between 2009 and 2012 in the share of students with access to computers at school



1. PISA 2009 data are missing for Costa Rica, Mexico, Shanghai-China and Chinese Taipei.
Note: White symbols indicate differences between PISA 2009 and PISA 2012 that are not statistically significant.
Countries and economies are ranked in descending order of the percentage of students with access to a computer at school in 2012.
Source: OECD, PISA 2012 Database, Table 2.9.
StatLink http://dx.doi.org/10.1787/888933252791

■ Figure 2.13 ■

Change between 2009 and 2012 in the share of students with access to the Internet at school



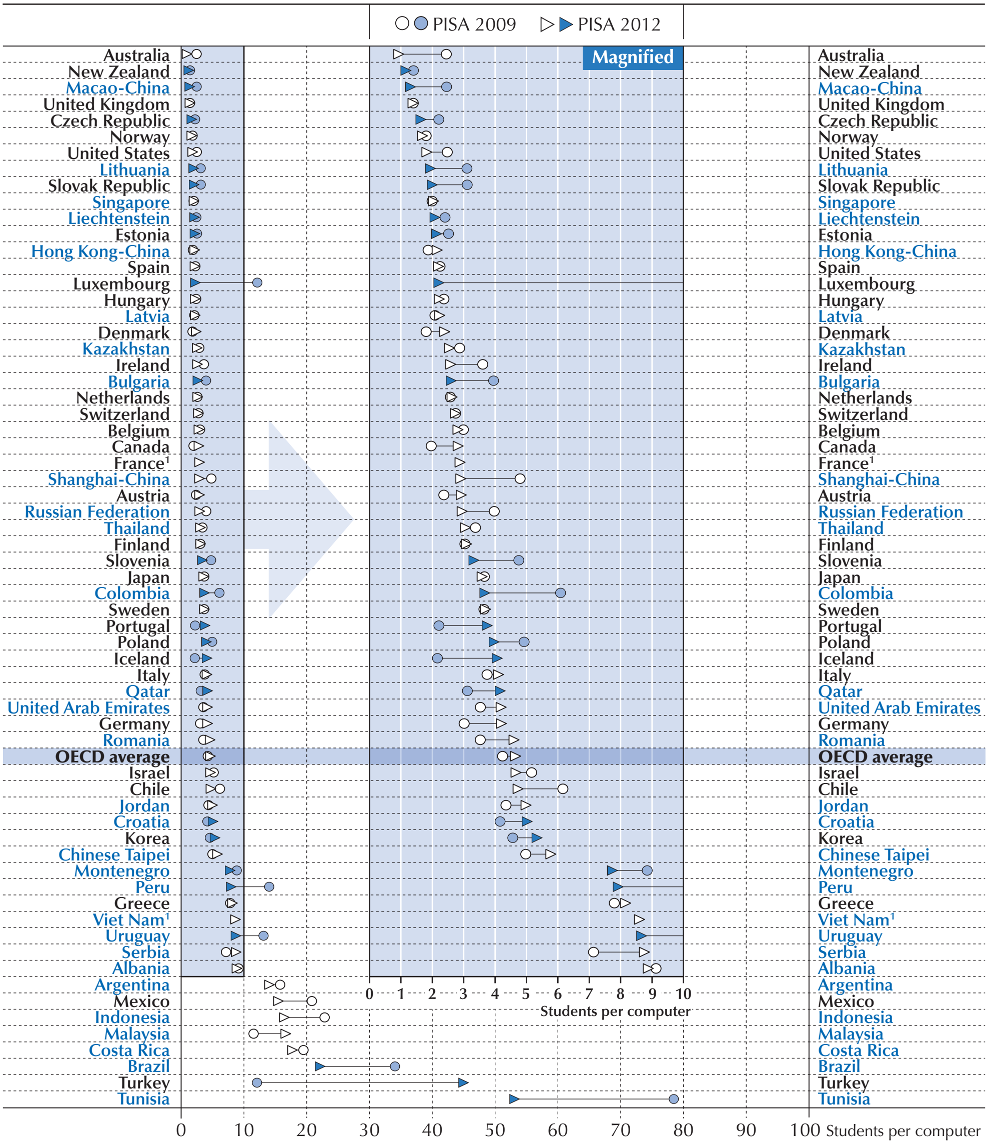
1. PISA 2009 data are missing for Costa Rica, Mexico, Shanghai-China and Chinese Taipei.
Note: White symbols indicate differences between PISA 2009 and PISA 2012 that are not statistically significant.
Countries and economies are ranked in descending order of the percentage of students using the Internet at school in 2012.
Source: OECD, PISA 2012 Database, Table 2.10.
StatLink http://dx.doi.org/10.1787/888933252808

Still, a stable, or even declining, share of students reporting access to computers and the Internet at school implies that any increase in the average extent to which students used computers in school between 2009 and 2012 (Figure 2.2) results from changes in the frequency and variety of uses rather than from changes in the share of students using computers at school.

■ Figure 2.14 ■

Change between 2009 and 2012 in the number of students per school computer

Mean student-computer ratio for 15-year-old students in the modal grade



1. PISA 2009 data are missing for France and Viet Nam.

Notes: White symbols indicate differences between PISA 2009 and PISA 2012 that are not statistically significant.

Only schools with at least 10 students in the national modal grade for 15-year-olds are included. The number of students per computer is based on principals' reports about the number of students in the national modal grade for 15-year-olds and on the number of computers available for these students. In schools where no computer is available, the number of students per computer is set at the number of students reported by the principal plus 1.

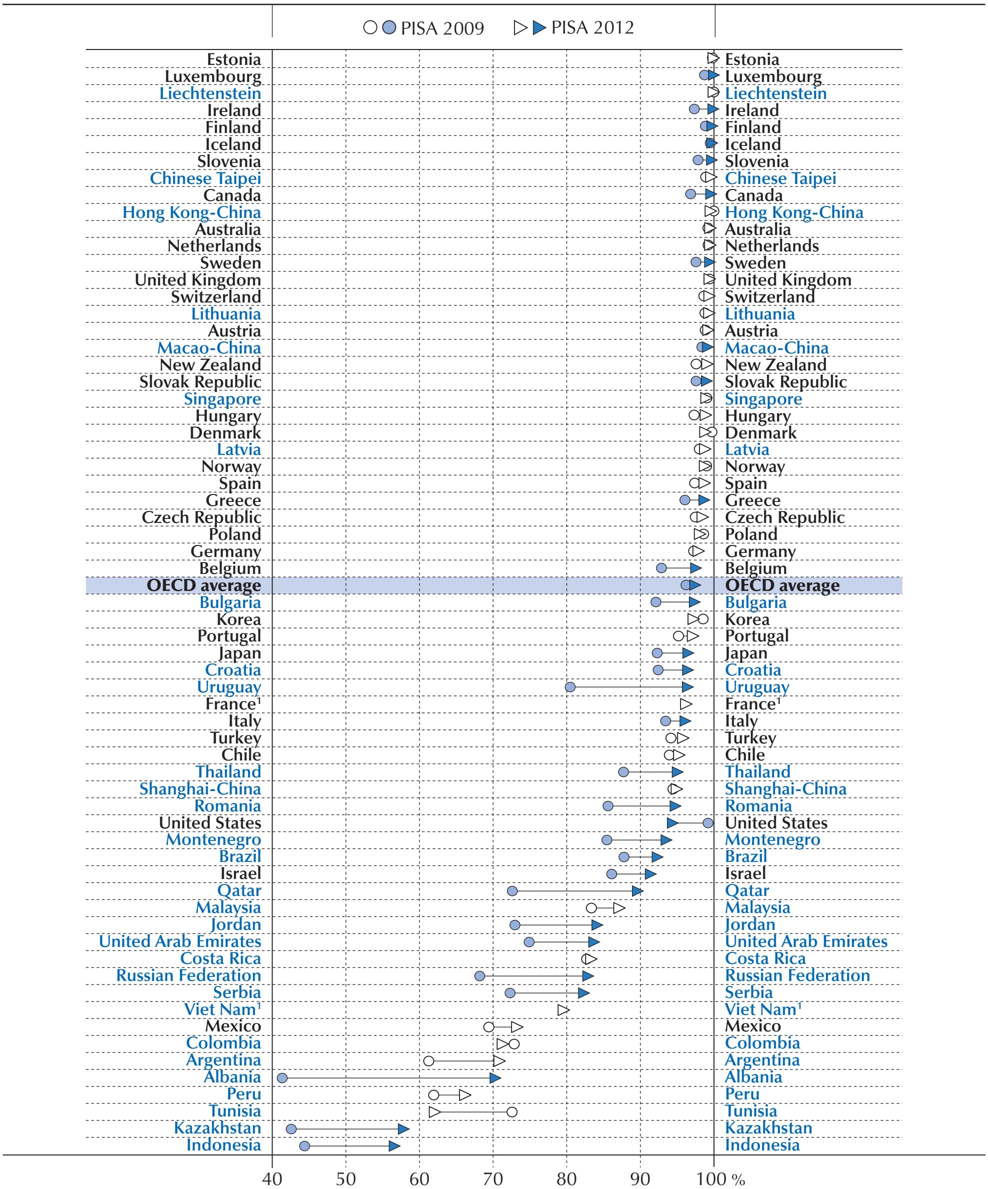
Countries and economies are ranked in ascending order of the student-computer ratio in 2012.

Source: OECD, PISA 2012 Database, Table 2.11.

StatLink http://dx.doi.org/10.1787/888933252810

■ Figure 2.15 ■

Change between 2009 and 2012 in the share of school computers that are connected to the Internet



1. PISA 2009 data are missing for France and Viet Nam.
Note: White symbols indicate differences between PISA 2009 and PISA 2012 that are not statistically significant.
Countries and economies are ranked in descending order of the share of school computers that are connected to the Internet in 2012.
Source: OECD, PISA 2012 Database, Table 2.11.
StatLink http://dx.doi.org/10.1787/888933252826

The rise of mobile computers in schools

Even if the quantity of resources did not change, increases in the intensity of computer use may still be related to improvements in the quality of schools' ICT infrastructure. Whether students can access computers in their classrooms or only in separate computer labs or at the school library makes a big difference in teachers' willingness to use computers in their teaching. Laptop and tablet computers offer much greater flexibility than desktop computers, and PISA data show that more and more schools have opted for these mobile computing solutions (Table 2.9).[5]

In 2012, desktop computers remained the most common form of computers in schools in every country. But the share of students with access to laptop computers at school increased by 8 percentage points between 2009 and 2012, on average across OECD countries, while over the same period the share of students with access to desktop computers declined by 3 percentage points. By 2012, 43% of students, on average, had access to laptops at school, and 11% had access to tablets. In 2012, the highest rates of student access to school laptops were observed in Denmark (91%), Australia (89%), Norway (87%), Sweden (75%) and the Russian Federation (64%). Laptop-acquisition programmes have expanded access to laptops by over 20 percentage points in Australia, Chile, Sweden and Uruguay. School tablets, on the other hand, were available to more than one in five students in Denmark (35%), Jordan (29%), Singapore (23%) and Australia (21%) in 2012 (Table 2.9).

Only in a few cases have laptop- or tablet-acquisition programmes actually expanded access to computers in schools; in most cases, tablets or laptops seem to have entered those schools where desktop computers were already available, thus broadening the variety of ICT devices. The most notable exceptions are Australia, Spain and Uruguay, where the increased availability of computers at school is entirely attributable to laptop or tablet computers (Table 2.9).

Although not considered computers, other ICT devices also entered schools between 2009 and 2012. Among these, e-book readers were available at school for more than one in five students in Jordan (39%), Greece (37%), Serbia (23%), Mexico (22%), Chile and Hungary (20%) (Table 2.9).

How school infrastructure trends are related to the use of ICT

PISA data on the types of devices available to students at school indirectly confirm that school ICT-acquisition programmes between 2009 and 2012 increasingly favoured mobile devices, such as laptops, and sometimes handheld devices, such as tablets or e-readers. As a result, by 2012, many students no longer had to move to separate computer labs, school libraries or specific locations within the classroom to access computers; rather, computers could be available everywhere, anytime, thus expanding the range of activities and situations in which they could be used.

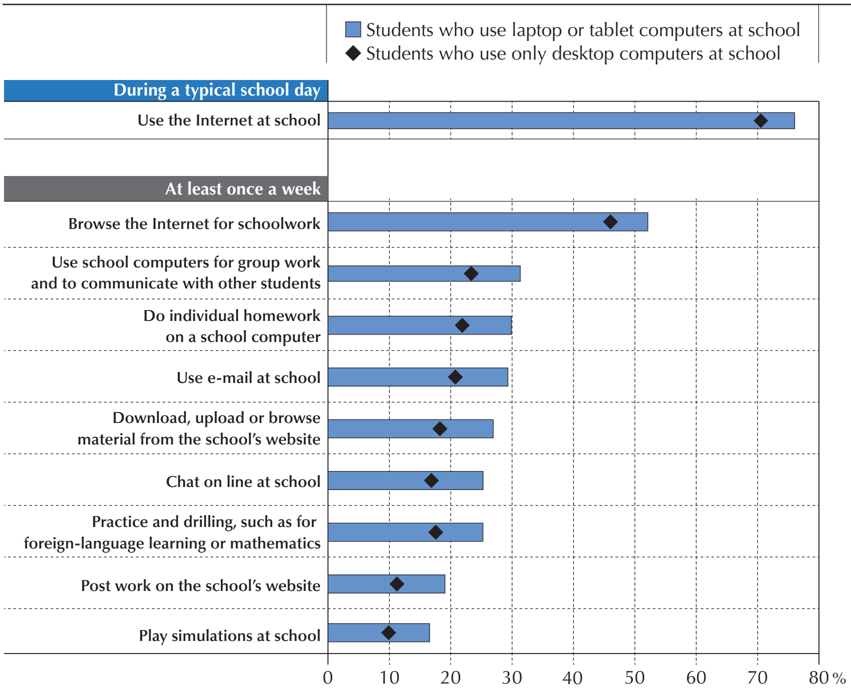
Between 2009 and 2012, the share of students using laptop computers increased, on average across OECD countries, while the overall share of students using computers remained stable, and the share of students using desktop computers declined. This evolution was particularly strong in Australia and Sweden. In both countries, laptop computers were used by only a minority of students in 2009, but by 2012 these devices had surpassed desktop computers as the most commonly used computers in schools (Table 2.3).

A comparison between students who use desktop computers only and students who use laptops and tablet computers at school, sometimes in addition to desktop computers, shows that computer use at school is significantly more frequent and more varied among the latter group. There is a significant difference in the percentage of students who use the Internet at school or regularly (i.e. at least once a week) engage in any of the activities examined in the PISA ICT questionnaire, depending on what device is available. For instance, while 27% of laptop or tablet users download, upload or browse material from the school's website at least once or twice a week, only 18% of desktop users do (Figure 2.16).

■ Figure 2.16 ■

Use of computers at school among desktop and laptop or tablet users

Percentage of students who reported engaging in each activity
(OECD average)

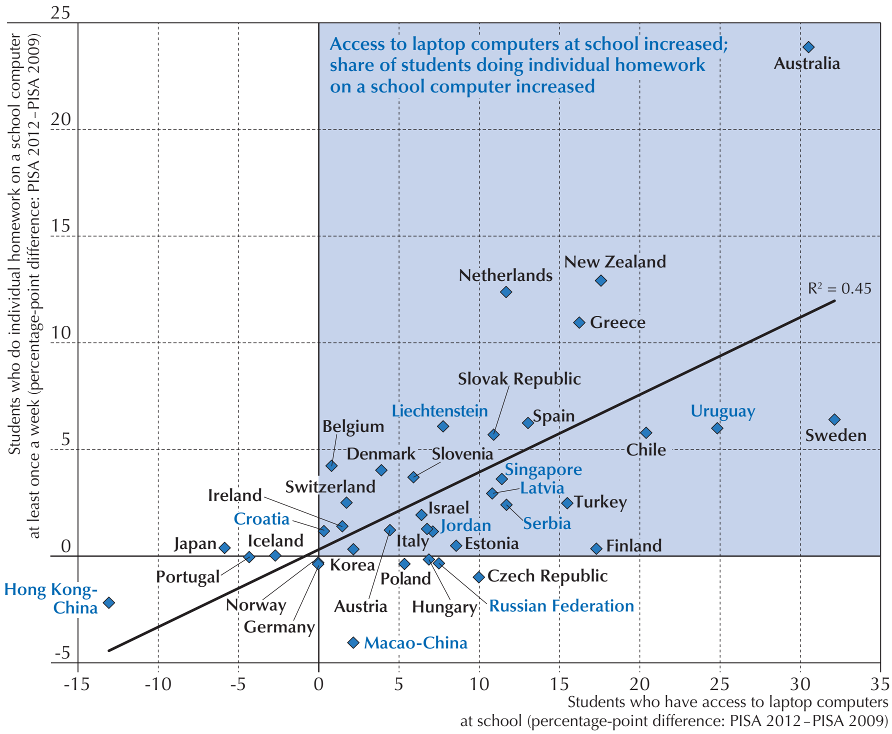


Source: OECD, PISA 2012 Database, Table 2.12.
StatLink http://dx.doi.org/10.1787/888933252838

At the system level, countries and economies with the largest increases in the share of frequent users are often those that implemented laptop- or tablet-expansion programmes (Figure 2.17). For instance, the share of students who frequently do their individual homework on school computers grew by more than 10 percentage points in Australia, Greece, the Netherlands and New Zealand – all countries where the share of students who have access to laptop computers at school increased by a similar degree.

■ Figure 2.17 ■

Relationship between the change in ICT use at school and increased access to laptops at school



Source: OECD, PISA 2012 Database, Tables 2.1 and 2.9.
StatLink http://dx.doi.org/10.1787/888933252847

However, PISA data also show that greater use of ICT at school did not always coincide with hardware-expansion programmes. In fact, previous studies show that the uptake of new technologies in schools is largely dependent on whether teachers are offered professional development activities to help them integrate new tools into their classroom practice (Hennessy and London, 2013). It is also the case that teachers with more experience in integrating ICT in instruction sometimes spend less time using computers than novice users. Quantity does not always coincide with quality.

Curricula and the use of ICT at school for instruction

Teachers may find guidance and support in integrating ICT into teaching practice in official curriculum documents or in school policies. PISA asked school principals whether their school had a policy on how to use computers in mathematics classes, e.g. to guide teachers on the extent to which computers should be used in mathematics lessons or on what specific mathematics computer programme to use. On average across OECD countries, 32% of students attend schools whose principal reported that such a policy exists. This share ranges from 93% of students in Slovenia to less than 5% of students in Sweden (Table 2.14).

Within countries, the degree of computer use during mathematics instruction seems only weakly related to the existence of such school policies. Indeed, most of the variation in computer use during mathematics instruction lies within schools, as opposed to between schools (Table 2.14). The use of computers in mathematics lessons, it appears, depends on teacher and (perhaps) student-level factors, rather than on school-level policies, to a greater extent than for more general uses of computers at school (such as browsing the Internet for schoolwork).

In fact, only 11 countries/economies show a significant difference in the *index of computer use in mathematics lessons* between schools where a policy on ICT use for mathematics exists, and schools where there is no such policy. It may be that school policies are more concerned with qualitative aspects, such as how to use existing software, rather than quantitative aspects, such as whether to use computers at all. It may also be that school policies are occasionally introduced to limit the use of ICT during mathematics instruction, rather than to support it. The only country where school policies on how to use computers in mathematics classes make a large difference in students' use of computers is Denmark. Interestingly, in Denmark the large between-schools variation in computer use during mathematics instruction also indicates the existence of coordinated practices among teachers in the same school (Table 2.14).

Other policies not directly related to ICT, such as the national curriculum, may play a more important role in supporting or discouraging the integration of ICT into teaching. Figure 2.18 shows whether using ICT in mathematics classes is related to the content to which students are exposed during lessons. This is determined using students' answers about how often, during their mathematics lessons, they have encountered four types of tasks: word problems, formal mathematics problems, applied tasks set in a mathematical context, and applied tasks where – as in most PISA problems – students have to apply their knowledge of mathematics to real-world contexts (see Box 2.1).

Box 2.1. **PISA measures of exposure to different mathematics tasks**

Four questions from the PISA student questionnaire were used to measure students' exposure to different types of content during mathematics lessons. Each question presented students with two examples of mathematics tasks and asked students not to solve them, but to report whether they had encountered similar types of problems "frequently", "sometimes", "rarely" or "never" during their mathematics lessons. The example tasks are shown below.

Question 1 – Word problems

Below are examples of tasks that require you to understand a problem written in text and perform the appropriate calculations. Usually the problem talks about practical situations, but the numbers and people and places mentioned are made up. All the information you need is given.

1. <Ann> is two years older than <Betty> and <Betty> is four times as old as <Sam>. When <Betty> is 30, how old is <Sam>?

2. Mr <Smith> bought a television and a bed. The television cost <$625> but he got a 10% discount. The bed cost <$200>. He paid <$20> for delivery. How much money did Mr <Smith> spend?

...

Question 2 – Formal mathematics tasks

Below are examples of another set of mathematical skills.

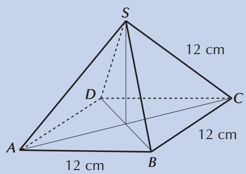
1) Solve 2x + 3 = 7.

2) Find the volume of a box with sides 3m, 4m and 5m.

Question 3 – Applied mathematics tasks – mathematics contexts

In the next type of problem, you have to use mathematical knowledge and draw conclusions. There is no practical application provided. Here are two examples.

1) Here you need to use geometrical theorems:



Determine the height of the pyramid.

2) Here you have to know what a prime number is:

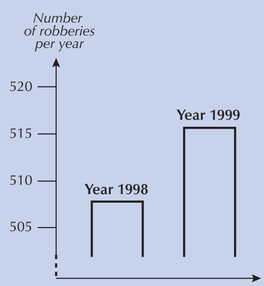
If n is any number: can $(n+1)^2$ be a prime number?

Question 4 – Applied mathematics tasks – real-world contexts

In this type of problem, you have to apply suitable mathematical knowledge to find a useful answer to a problem that arises in everyday life or work. The data and information are about real situations. Here are two examples.

Example 1

A TV reporter says "This graph shows that there is a huge increase in the number of robberies from 1998 to 1999."



Do you consider the reporter's statement to be a reasonable interpretation of the graph?
Give an explanation to support your answer.

Example 2

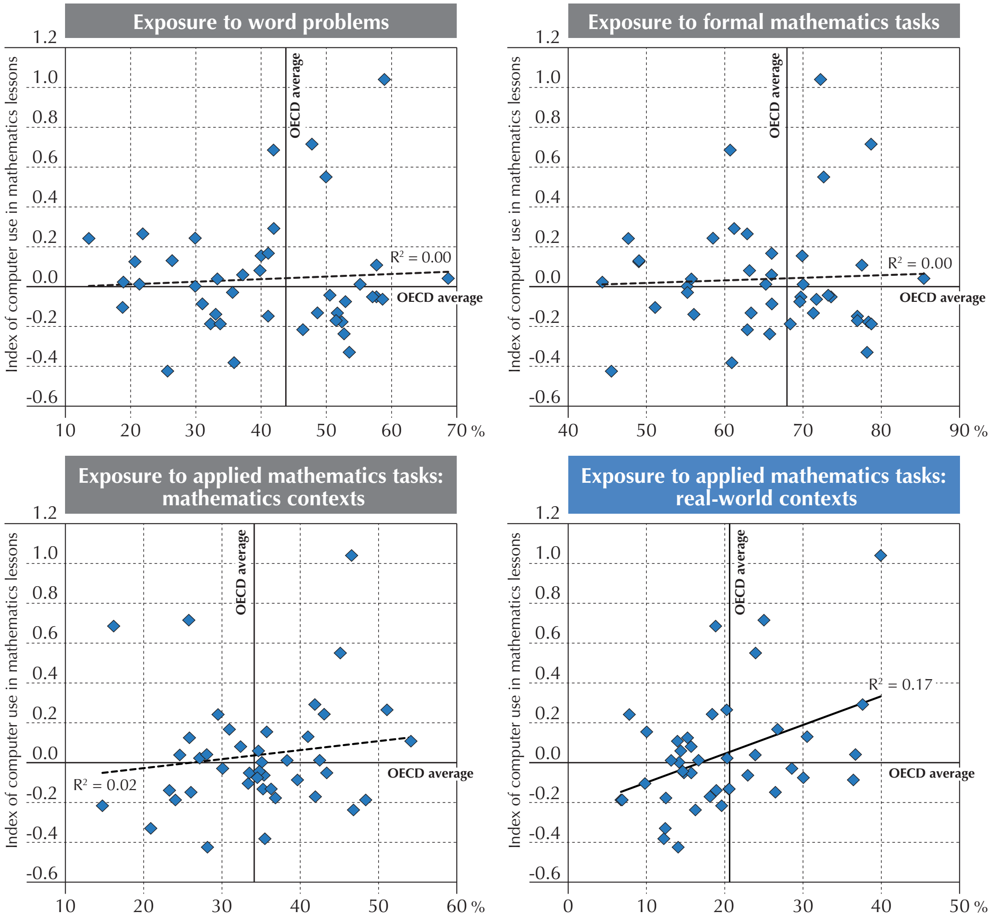
For years the relationship between a person's recommended maximum heart rate and the person's age was described by the following formula:
Recommended maximum heart rate = 220 – age

Recent research showed that this formula should be modified slightly. The new formula is as follows:
Recommended maximum heart rate = 208 – (0.7 × age)

From which age onwards does the recommended maximum heart rate increase as a result of the introduction of the new formula? Show your work.

■ Figure 2.18 ■

Relationship between computer use in mathematics lessons and students' exposure to various mathematics tasks



Notes: The dotted lines indicate non-significant relationships. The solid line indicates a correlation higher than 0.4 (R^2 higher than 0.16).
For each chart, the horizontal axis represents the percentage of students who reported that they encounter the corresponding type of tasks "frequently" during mathematics lessons.
Each diamond represents the mean values of a country/economy.
Source: OECD, PISA 2012 Database, Table 2.15.
StatLink http://dx.doi.org/10.1787/888933252859

Across countries, greater exposure to formal mathematics or word problems is not strongly related to differences in computer use during mathematics lessons. In contrast, countries where computers are used more during mathematics instruction tend to be those where students have greater-than-average exposure to applied mathematics tasks – particularly to tasks in which they can practice their mathematics skills in real-world contexts. This shows that the content of the curriculum can influence the desirability, and use, of computers for instruction (Figure 2.18).

HOW ICT USE IS RELATED TO PEDAGOGICAL PRACTICES IN MATHEMATICS

According to the literature on educational effectiveness, a number of classroom variables appear to be related to better learning outcomes, particularly classroom climate and instructional quality. How is computer use during mathematics lessons linked to student discipline and the quality of instruction?

Instructional quality is difficult to measure, as existing evidence suggests that there is no single best way of teaching. Close monitoring, adequate pacing and classroom management as well as clarity of presentation, well-structured lessons and informative and encouraging feedback – which are good instructional practices – have generally been shown to have a positive impact on student achievement, as they help to create an orderly classroom environment and maximise learning time (OECD, 2013c).

This is not enough, however. Teachers provide learning opportunities; but to be effective, those opportunities must be recognised and seized by the student. This is particularly important if students are to go beyond rote learning and to develop the skills that they can confidently apply in new contexts. For these reasons, teaching that fosters deep conceptual understanding involves more than "direct instruction". Based on results from the Trends in International Mathematics and Science Study (TIMSS) video study, Klieme, Pauli and Reusser (2009) proposed three pillars for quality teaching: clear and well-structured classroom management; student orientation; and cognitive activation with challenging content. The PISA measures of mathematics teaching, which distinguish structure (teacher-directed instruction), student orientation, formative assessment and cognitive activation in mathematics lessons, are grounded in this framework (see Box 2.2) (OECD, 2013c).

Box 2.2. PISA 2012 indices of mathematics teaching practices

Two questions were used to gauge mathematics teachers' classroom practices in PISA 2012. In each of them, the question stem was "how often do these things happen in your mathematics lessons?", followed by a series of items describing teacher behaviours. Students were asked to report on the frequency with which they observed these behaviours on a four-point scale (from "every lesson" to "never or hardly ever" in question ST79; from "always or almost always" to "rarely" in question ST80).

These behaviours were grouped to form the four indices of teacher behaviour (structuring practices, student-oriented practices, formative assessment practices and cognitive activation practices), as follows:

Structuring practices (teacher-directed instruction):

ST79Q01	The teacher sets clear goals for our learning
ST79Q02	The teacher asks me or my classmates to present our thinking or reasoning at some length
ST79Q06	The teacher asks questions to check whether we have understood what was taught
ST79Q08	At the beginning of a lesson, the teacher presents a short summary of the previous lesson
ST79Q15	The teacher tells us what we have to learn

...

Student-oriented practices:

ST79Q03	The teacher gives different work to classmates who have difficulties learning and/or to those who can advance faster
ST79Q04	The teacher assigns projects that require at least one week to complete
ST79Q07	The teacher has us work in small groups to come up with joint solutions to a problem or task
ST79Q10	The teacher asks us to help plan classroom activities or topics

Formative assessment practices:

ST79Q03	The teacher tells me about how well I am doing in my mathematics class
ST79Q04	The teacher gives me feedback on my strengths and weaknesses in mathematics
ST79Q07	The teacher tells us what is expected of us when we get a test, quiz or assignment
ST79Q10	The teacher tells me what I need to do to become better in mathematics

Cognitive activation practices:

ST80Q01	The teacher asks questions that make us reflect on the problem
ST80Q04	The teacher gives problems that require us to think for an extended time
ST80Q05	The teacher asks us to decide on our own procedures for solving complex problems
ST80Q06	The teacher presents problems for which there is no immediately obvious method of solution
ST80Q07	The teacher presents problems in different contexts so that students know whether they have understood the concepts
ST80Q08	The teacher helps us to learn from mistakes we have made
ST80Q09	The teacher asks us to explain how we have solved a problem
ST80Q10	The teacher presents problems that require students to apply what they have learned to new contexts
ST80Q11	The teacher gives problems that can be solved in several different ways

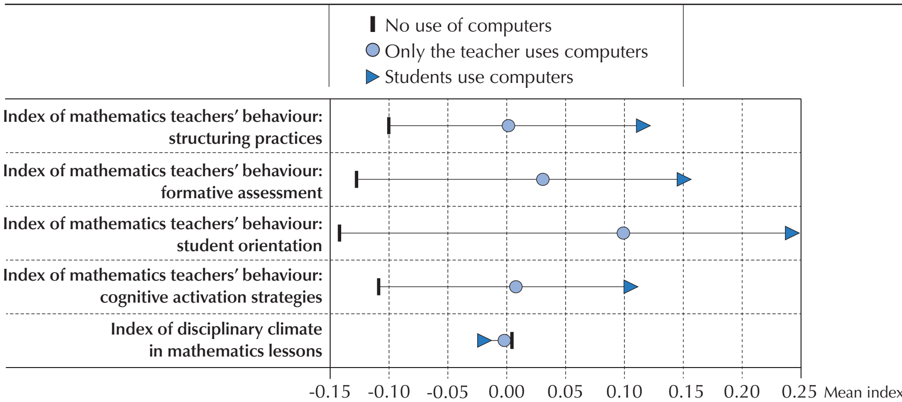
Several features of ICT support teachers in giving adaptive feedback to students and, more generally, individualising instruction; in other words, they support student-oriented and formative assessment behaviours in teachers' classroom practice. They also facilitate collaborative projects and enable teachers to extend the spatial and temporal boundaries of their lessons, thus creating the potential for cognitively challenging and engaging activities. In contrast, teachers cannot expect computers to be much help in managing the classroom or in certain structuring practices, such as presenting a short summary of the previous lesson at the beginning of each new lesson.

Is there a relationship, in PISA, between the degree of integration of technology in mathematics instruction and the quality of teachers' pedagogical practices? Figure 2.19 shows that, in general, students who use ICT during mathematics lessons more often describe their teachers as frequently using effective instructional strategies and behaviours, such as structuring practices (e.g. setting clear goals, asking questions to verify understanding), student-oriented practices (e.g. giving different work to students who have difficulties or who can advance faster, having students work in small groups), formative assessment (e.g. giving feedback on strengths and weaknesses), and cognitive activation (e.g. giving problems that require students to apply what they have learned to new contexts and/or giving problems that can be solved in several different ways).

■ Figure 2.19 ■

Teaching practices and disciplinary climate, by computer use in mathematics lessons

Mean indices (OECD average)



Note: All differences between students who reported using computers during mathematics lessons and students who reported computers are not used are statistically significant.
Source: OECD, PISA 2012 Database, Tables 2.13b, c, d, e and f.
StatLink http://dx.doi.org/10.1787/888933252861

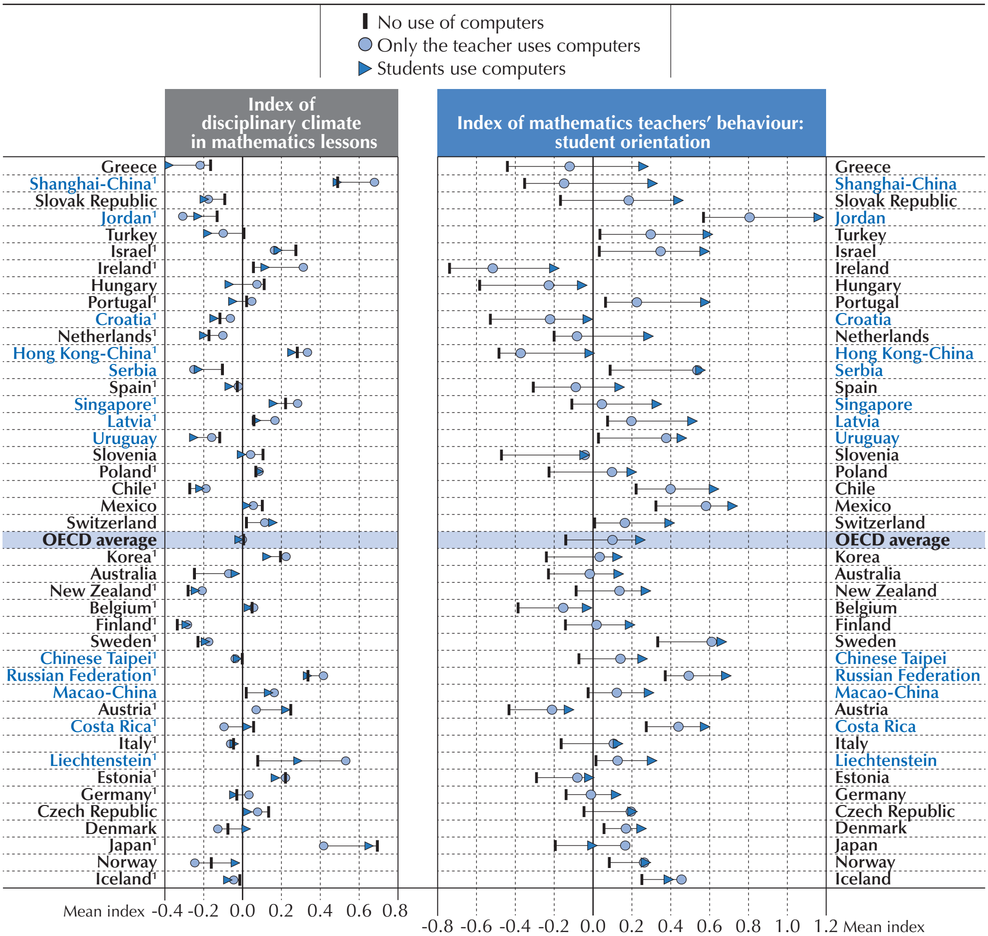
The strongest association between ICT use and teachers' classroom practices, by a large margin, is with student-oriented practices and formative assessment practices. Uniformly positive associations may raise the suspicion that the relation between ICT use and teacher behaviour is not direct and specific, but hinges on another factor that is associated with both variables, such as class time, teacher experience, or student response style. In contrast, the strong association with student-oriented practices, which include individualised pacing, collaborative learning and project-based learning, suggests a specific association: these are precisely the kinds of practices that can benefit from ICT. Computers are also extremely efficient at giving individualised feedback (formative assessment) to users in well-designed learning situations.

The evidence from PISA supports the conclusion that teachers who are more inclined and better prepared for student-oriented teaching practices, such as group work, individualised learning, and project work, are more willing to integrate computers into their lessons, when the required resources are available. Indeed, a specific association between teachers' use of student-oriented teaching practices and the use of ICT in mathematics lessons is observed not only within countries and economies, but also at the system level. When countries and economies are compared against each other, the relationship between the average frequency of student-oriented teaching practices and the extent to which ICT is used in mathematics classes is strong and significant (Figures 2.20 and 2.21).

PISA also shows that in most countries and economies there is no association between the disciplinary climate in mathematics classes and computer use by students (disciplinary climate refers to students' perceptions that mathematics lessons are orderly, with minimal loss of instruction time due to noise or indiscipline). However, some countries show positive or negative associations between the two. While in Australia, Denmark, Macao-China, Norway and Switzerland students who use computers during mathematics instruction reported better disciplinary climate in their classroom than students who do not use computers, in eleven countries/economies (the Czech Republic, Greece, Hungary, Israel, Mexico, Portugal, Serbia, the Slovak Republic, Slovenia, Turkey and Uruguay), the disciplinary climate is significantly worse when students reported greater use of computers (Figure 2.20).

■ Figure 2.20 ■

Student-oriented teaching and disciplinary climate, by computer use in mathematics lessons



1. Countries and economies in which differences are not statistically significant between students who reported using computers in mathematics lessons and students who reported computers are not used.

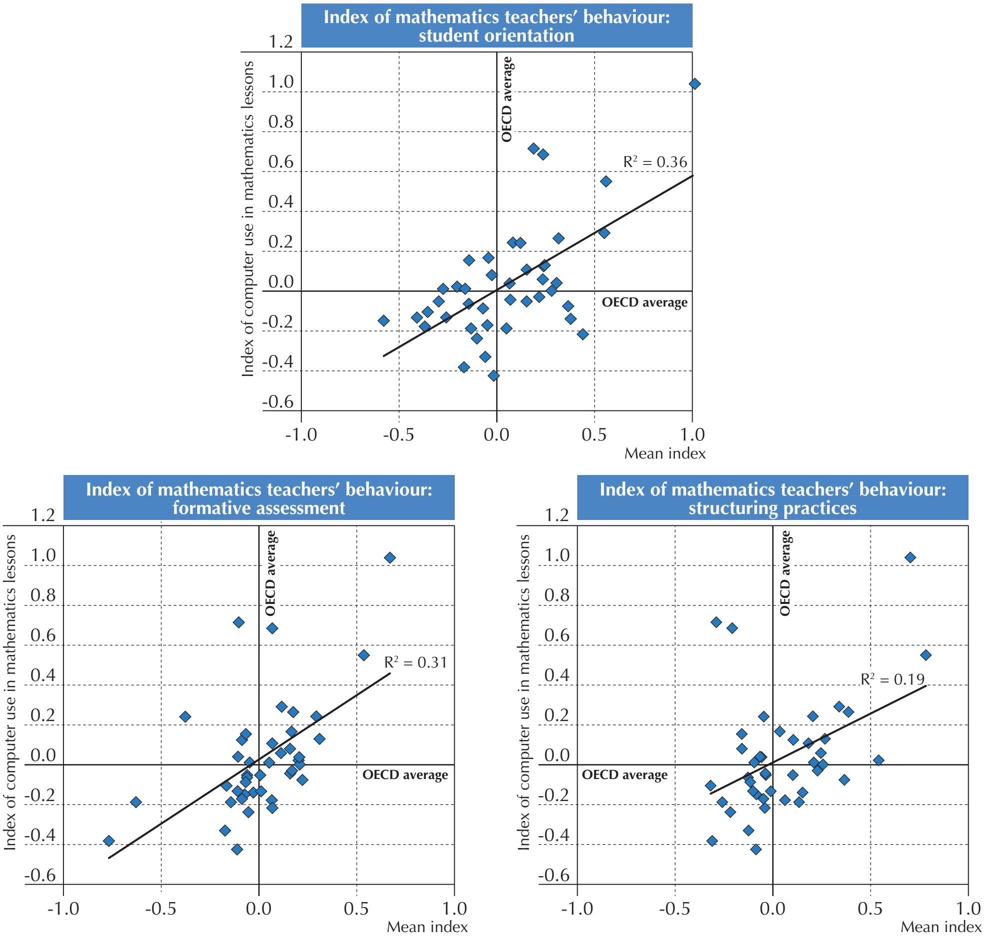
Countries and economies are ranked in descending order of the difference in the mean index of mathematics teachers' behaviour (student orientation) *between students who reported using computers during mathematics lessons and students who reported computers are not used.*

Source: OECD, PISA 2012 Database, Tables 2.13b and 2.13e.

StatLink http://dx.doi.org/10.1787/888933252876

■ Figure 2.21 ■

Relationship between computer use in mathematics lessons and teachers' behaviour



Note: Each diamond represents the mean values of a country/economy.
Source: OECD, PISA 2012 Database, Table 2.15.
StatLink http://dx.doi.org/10.1787/888933252886

One possible reason for the difference is that in the former group of countries/economies, teachers have more experience integrating technology in teaching, while in the latter group, this process is only starting. As a result, teachers' low level of confidence in using ICT, and possibly a lack of professional development activities to help teachers learn how to use new tools in their teaching, may lead to disorder in the classroom when computers are used. In all systems participating in the TALIS survey, teachers cited improving their ICT skills as one of the most important priorities for their professional development (OECD, 2014a).[6] Integrating technology into teaching should always be done in the service of pedagogy (OECD, 2010).

Notes

1. The *Technical Report* (OECD, 2014b) provides details on how indices derived from the ICT familiarity questionnaire were scaled.

2. Values for the *index of ICT use at school* cannot be directly compared to the corresponding 2009 index. The response categories for items included in the construction of this index changed between the 2009 and 2012 surveys. Nevertheless, it is possible to compare relative rankings. A comparison of rankings relative to the OECD average shows that, in some countries and economies, such as Australia, Greece, Spain and Uruguay, the frequency and variety of ICT use in schools increased more than the average increase, while in other countries and economies, notably Hong Kong-China, Hungary, Iceland and Portugal, all of which were at or above the OECD average in 2009, the frequency and variety of ICT use at school fell below the OECD average by 2012.

3. In this context, "computers" include desktop, laptop and tablet computers, but do not include other ICT devices, such as smartphones.

4. For results based on the Teaching and Learning International Survey (TALIS), see OECD, 2014a and OECD, 2015.

5. Tablet computers became popular only after 2010, when the first Apple iPad® was released. Although no question about tablets was asked in PISA 2009, it can be safely assumed that no student had access to tablet computers during that survey.

6. In Brazil, France, Iceland, Italy, Japan, Malaysia and Sweden, over one in four teachers reported that they have a high level of need for professional development in the area of ICT skills for teaching.

Chapter 2 tables are available on line at http://dx.doi.org/10.1787/edu-data-en.

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.

References

Avvisati, F., S. Hennessy, R.B. Kozma and **S. Vincent-Lancrin** (2013), "Review of the Italian strategy for digital schools", *OECD Education Working Papers*, No. 90, OECD Publishing, Paris, http://dx.doi.org/10.1787/5k487ntdbr44-en.

Frost, D. and **J. Durrant** (2003), "Teacher leadership: Rationale, strategy and impact", *School Leadership & Management*, Vol. 23/2, pp.173-186.

Harris, A. (2005), "Teacher leadership: More than just a feel-good factor?", *Leadership and Policy in Schools, Vol.* 4/3, pp. 201-219.

Hennessy, S. and **L. London** (2013), "Learning from international experiences with interactive whiteboards: The role of professional development in integrating the technology", *OECD Education Working Papers*, No. 89, OECD Publishing, Paris, http://dx.doi.org/10.1787/5k49chbsnmls-en.

Horn, I. S. and **J.W. Little** (2010), "Attending to problems of practice: Routines and resources for professional learning in teachers' workplace interactions," *American Educational Research Journal*, Vol. 47/1, pp. 181-217.

Klieme, E., C. Pauli and **K. Reusser** (2009), "The Pythagoras study: Investigating effects of teaching and learning in Swiss and German mathematics classrooms", in Tomáš, J. and T. Seidel (eds.), *The Power of Video Studies in Investigating Teaching and Learning in the Classroom*, pp. 137-160, Waxmann Verlag GmbH, Münster, Germany.

Little, J.W. (1982), "Norms of collegiality and experimentation: Workplace conditions of school success", *American Educational Research Journal, Vol.* 19/2, pp. 325-340.

Livingstone, S. (2011), "Critical reflections on the benefits of ICT in education", *Oxford Review of Education*, Vol. 38/1, pp. 9-24.

OECD (2015), "Embedding professional development in schools for teacher success", *Teaching in Focus*, No. 10, OECD Publishing, Paris, http://dx.doi.org/10.1787/5js4rv7s7snt-en.

OECD (2014a), "Developing and supporting teachers", in OECD, *TALIS 2013 Results: An International Perspective on Teaching and Learning*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264196261-7-en.

OECD (2014b), *PISA 2012 Technical Report*, PISA, OECD, Paris, www.oecd.org/pisa/pisaproducts/pisa2012technicalreport.htm.

OECD (2013a), *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264204256-en.

OECD (2013b), *PISA 2012 Results: What Makes Schools Successful (Volume IV): Resources, Policies and Practices*, PISA, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264201156-en.

OECD (2013c), *PISA 2012 Assessment and Analytical Framework: Mathematics, Reading, Science, Problem Solving and Financial Literacy*, PISA, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264190511-en.

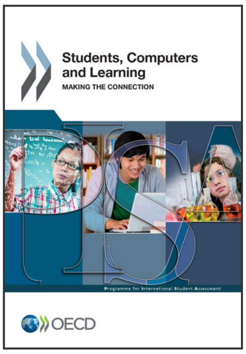
OECD (2012), *The Protection of Children Online: Recommendation of the OECD Council: Report on Risks Faced by Children Online and Policies to Protect Them*, OECD, Paris, www.oecd.org/sti/ieconomy/childrenonline_with_cover.pdf.

OECD (2011), *PISA 2009 Results: Students On Line: Digital Technologies and Performance (Volume VI)*, PISA, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264112995-en.

OECD (2010), *Inspired by Technology, Driven by Pedagogy: A Systemic Approach to Technology-Based School Innovations*, Educational Research and Innovation, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264094437-en.

Resnick, L.B., J.P. Spillane, P. Goldman and **E.S. Rangel** (2010), "Implementing innovation: From visionary models to everyday practice", in Dumont, H., D. Instance and F. Benavides (eds.), *The Nature of Learning. Using Research to Inspire Practice*, pp. 285-315. OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264086487-en.

Tondeur, J., J. van Braak, G. Sang, J. Voogt, P. Fisser and **A. Ottenbreit-Leftwich** (2012), "Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence", *Computers & Education*, Vol. 59/1, pp. 134-44.



From:

Students, Computers and Learning

Making the Connection

Access the complete publication at:
https://doi.org/10.1787/9789264239555-en

Please cite this chapter as:

OECD (2015), “Integrating Information and Communication Technology in Teaching and Learning”, in *Students, Computers and Learning: Making the Connection*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264239555-5-en

OECD