6

How Computers are Related to Students' Performance

Despite considerable investments in computers, Internet connections and software for educational use, there is little solid evidence that greater computer use among students leads to better scores in mathematics and reading. This chapter examines the relationship among computer access in schools, computer use in classrooms, and performance in the PISA assessment.

In the past 15 years, schools and families around the world spent a substantial amount of money on computers, Internet connections, and software for educational use. Yet the benefits of these investments for children's learning are not clear. While relatively abundant research has evaluated the effects of public investments in computers for education on education outcomes, more often than not these evaluations fail to identify any positive association between an increase in computer use and better test scores in mathematics and reading (see Bulman and Fairlie [forthcoming] for a recent review).

A better understanding of how computers affect education outcomes is thus critical for investing in education technology. This chapter explores the relationship among computer access in schools, computer use in classrooms, and performance in PISA assessments.

What the data tell us

- Resources invested in ICT for education are not linked to improved student achievement in reading, mathematics or science.

- In countries where it is less common for students to use the Internet at school for schoolwork, students' performance in reading improved more rapidly than in countries where such use is more common, on average.

- Overall, the relationship between computer use at school and performance is graphically illustrated by a hill shape, which suggests that limited use of computers at school may be better than no use at all, but levels of computer use above the current OECD average are associated with significantly poorer results.

PISA allows for analysing relationships between performance and computer access and use across countries/economies as well as within education systems, across students and schools. The strength of PISA data lies in the wide range of contexts covered. However, in non-experimental, cross-sectional data such as those gathered through PISA, even sophisticated statistical techniques cannot isolate the cause-and-effect relationship among computer access and use of computers, on the one hand, and performance, on the other. With this data, patterns of correlation can be identified, but these must be interpreted carefully, because several alternative explanations could give rise to similar patterns. Box 6.1 discusses in greater detail the problem of identifying causal relationships between computer investments and education outcomes.

This chapter interprets the findings of analyses on PISA data in light of the findings in the wider literature. Experimental findings that can clearly identify causal links in the relationship between computer access and use and academic performance are highlighted in the discussion.

TECHNOLOGY INVESTMENTS AND TRADE-OFFS

When comparing countries/economies whose schools vary in their information and communication technology (ICT) resources, it is important to keep in mind that countries/economies often vary, in related ways, across other dimensions as well. Likewise within countries, differences in the ICT resources of schools may be related to other differences across schools.

Box 6.1. **Interpreting relationships among performance, computer access and use of computers at the system, school and student levels**

Using PISA data, it is possible to relate students' performance to their exposure to computers, as reported by the students themselves or by school principals. It is also possible, at the system level, to relate aggregate indicators of education outcomes to students' average level of exposure to computers within a system – a proxy measure for a country's/economy's effort in integrating information and communication technology (ICT) in education.

There may be several explanations for observing strong relationships between student performance and exposure to computers. These relationships could reflect a cause-and-effect association between computer access/use and performance; but they could also reflect the inverse relationship, whereby (expected) performance drives investment in computers. Countries, schools and families that are less satisfied with their students' performance, for instance, may choose to invest more in new tools or be keener to experiment them in the hope of improving these results. Even in the absence of causal links, these relationships could reflect associations of computer access and use with other variables, such as the resources available, the difficulty of attracting good teachers, etc., which are themselves related to performance.

Within school systems, the main obstacle to interpreting associations as cause-and-effect is the non-random allocation of computers to students, schools, school types and school tracks. Nothing guarantees that students who are more exposed to computers can be compared with students who are less exposed, and that the observed performance differences can be attributed to such differences in exposure. Even when comparing students of similar socio-economic status, those schools and students that have and use computers more differ in several observable and non-observable ways from those that have more limited access to computers, or use them less. For instance, greater availability of computers at school may reflect a principal's capacity to raise funds, the teachers' willingness to lead change, or other principal and teacher characteristics that could not be accounted for in a non-experimental analysis. What students do with computers also depends on what they are able to do, i.e. their level of skill. Non-random selection and reverse causality thus plague within-country analyses, even after accounting for observable differences across students and schools.

The analyses that relate the overall performance of school systems to investments in computers and connectivity, or to levels of computer use at school, run into similar difficulties. A cross-country correlation is a simple measure of the degree to which two variables are associated with each other, but does not prove a causal link between the two, nor the direction of this link. While the correlations are examined after accounting for differences in per capita income, other factors beyond a country's/economy's income level could be related to these variables and explain the association.

In particular, ICT resources are related to the resources available for schools. Countries with low expenditures on education, and low per capita income, tend to have fewer computers per student in their schools than countries with high expenditures on education (Figure 6.1).

■ Figure 6.1 ■
Number of computers available to students and expenditure on education
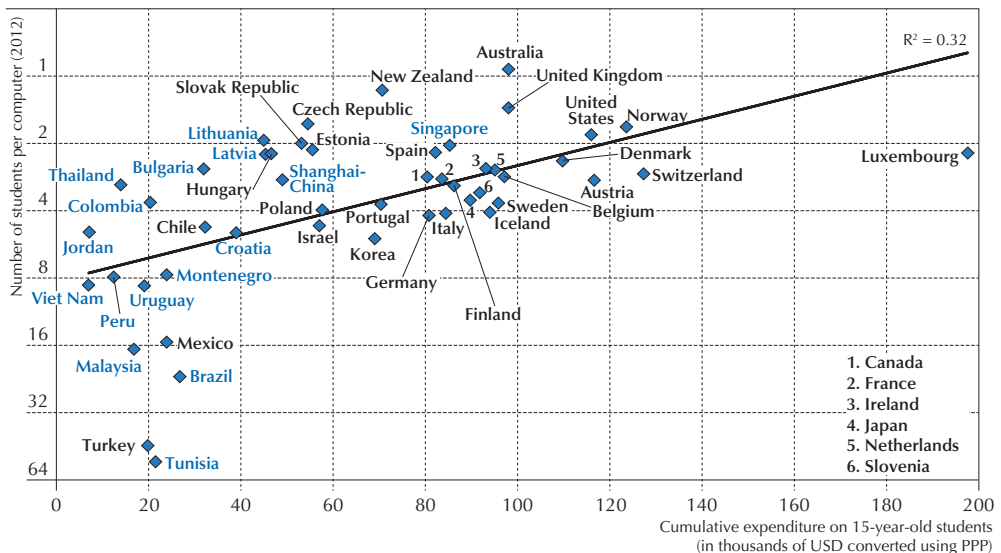
Notes: The horizontal axis reports the cumulative expenditure by educational institutions per student from age 6 to 15, in equivalent USD converted using PPP for GDP. Data for most countries refer to 2010.
Source: OECD, PISA 2012 Database, Table IV.3.1 (OECD, 2013) and Table 2.11.
StatLink ⌐🖳🖵 http://dx.doi.org/10.1787/888933253247

While investments in computer hardware, software and connectivity appear to increase with the resources spent on education, it is also clear that these investments compete for resources with other priorities. For a given level of resources at the country level, money spent on equipping schools with ICT could have been used for hiring additional teachers, increasing their salaries or investing in their professional development, or spent on other educational resources, such as textbooks. When interpreting the relationship between ICT investments and students' performance in terms of costs and benefits, it is important to include, among the costs, the forgone benefits of alternative uses of money (what economists refer to as the opportunity cost).

Similarly, computer use in classrooms and at home can displace other activities that are conducive to learning, or, instead, increase learning time by reducing recreational time or non-productive uses of classroom time. The net effect of computer use in classrooms and at home is likely to depend on whether computers displace other learning activities or, instead, increase the overall time that is spent learning or the effectiveness of learning processes.

HOW LEARNING OUTCOMES ARE RELATED TO COUNTRIES'/ECONOMIES' INVESTMENTS IN SCHOOL ICT RESOURCES

Figure 6.2 draws a complex picture of the relationship between countries'/economies' performance in PISA and the average level of access to and use of computers at school. While a few of the associations are positive, many correlations are negative, particularly in analyses that account for a country's/economy's income level.

Across countries and economies, the amount of ICT resources available to students is positively related to students' performance. However, much of this association reflects the overall amount of educational resources available to students, as well as school systems' past levels of performance. The strength of the relationship weakens considerably when adjusting the level of ICT resources for the variation in per capita income across countries/economies, and becomes mildly negative when also controlling for the system's average performance in earlier PISA assessments (Figure 6.2).

In fact, PISA data show that for a given level of per capita GDP and after accounting for initial levels of performance, countries that have invested less in introducing computers in school have improved faster, on average, than countries that have invested more. Results are similar across reading, mathematics and science (Figure 6.2).

Figure 6.3, for instance, shows that, between 2003 and 2012, students' performance in mathematics deteriorated in most countries that had reduced their student-computer ratios over the same period (after accounting for differences in per capita GDP).

One possibility is that such school resources were, in fact, not used for learning. But overall, even mesures of ICT use in classrooms and schools show often negative associations with student performance. Average reading proficiency, for instance, is not higher in countries where students more frequently browse the Internet for schoolwork at school. Figure 6.4 shows that in countries where it is more common for students to use the Internet at school for schoolwork, students' performance in reading declined, on average. Similarly, mathematics proficiency tends to be lower in countries/economies where the share of students who use computers in mathematics lessons is larger (Figure 6.2).

An alternative possibility is that resources invested in equipping schools with digital technology may have benefitted other learning outcomes, such as "digital" skills, transitions into the labour market, or other skills different from reading, mathematics and science.

However, the associations with ICT access/use are weak, and sometimes negative, even when results in digital reading or computer-based mathematics are examined, rather than results in paper-based tests (Figure 6.2). In addition, even specific digital reading competencies do not appear to be higher in countries where browsing the Internet for schoolwork is more frequent.

The average quality of students' online navigation, as measured through the *index of task-oriented browsing*, is unrelated to the share of students who frequently use the Internet at school (Figure 6.2). The *index of task-oriented browsing* reflects students' ability to plan and regulate their navigation behaviour on line, and to anticipate, by making an inference based on the available information, whether the target of a link is relevant or not to the task.

■ Figure 6.2 ■

Relationship between students' performance and computer access/use at school

Across all countries and economies

	Mean student performance in PISA 2012				Trends in student performance (annualised change)		Quality of navigation (mean index of task-oriented browsing)
	Mathematics	Reading	Computer-based mathematics	Digital reading	Mathematics	Reading	
A Correlation coefficients[1]							
Average number of computers per student[2]	**0.57**	**0.56**	**0.41**	0.36	-0.15	-0.38	**0.41**
Mean index of ICT use at school	-0.30	-0.30	**-0.47**	**-0.42**	**-0.45**	**-0.51**	-0.20
Mean index of computer use in mathematics lessons	-0.34	-0.38	-0.07	-0.09	-0.02	0.09	-0.05
Share of students browsing the Internet at school for schoolwork at least once a week	-0.23	-0.17	**-0.42**	-0.31	**-0.49**	**-0.55**	-0.06
B Partial correlation coefficients,[3] after accounting for GDP per capita[2]							
Average number of computers per student[2]	0.35	0.32	0.17	0.10	-0.13	-0.29	0.09
Mean index of ICT use at school	**-0.61**	**-0.62**	**-0.67**	**-0.66**	**-0.44**	**-0.50**	**-0.50**
Mean index of computer use in mathematics lessons	-0.26	-0.31	-0.18	-0.23	-0.07	0.05	-0.24
Share of students browsing the Internet at school for schoolwork at least once a week	**-0.55**	**-0.49**	**-0.61**	**-0.54**	**-0.47**	**-0.53**	-0.31
C Partial correlation coefficients,[3] after accounting for GDP per capita[2] and mean performance on the mathematics scale in PISA 2003							
Average number of computers per student[2]	-0.26	-0.23	**-0.40**	**-0.51**	-0.34	-0.29	-0.35
Mean index of ICT use at school	**-0.65**	**-0.50**	**-0.66**	**-0.57**	**-0.47**	**-0.66**	-0.32
Mean index of computer use in mathematics lessons	-0.09	-0.15	-0.01	-0.15	0.08	-0.11	-0.26
Share of students browsing the Internet at school for schoolwork at least once a week	**-0.65**	-0.38	**-0.71**	**-0.43**	**-0.51**	**-0.66**	-0.07

1. The correlation coefficient is a simple measure of association between two variables. It varies between -1 and 1, with 0 indicating no relationship.
2. The average number of computers per student and GDP per capita are measured in logarithms.
3. The partial correlation coefficient is an extension of the correlation coefficient. It corresponds to the correlation between the residuals from the regression of two variables on the confounding variables that need to be accounted for.
Notes: Values above 0.4 indicate strong positive associations and are reported in bold; values below -0.4 indicate strong negative associations and are reported in blue bold.
Each correlation coefficient is based on the highest number of available observations. However, because not all variables are observed across all countries/economies, the sample size varies across cells.
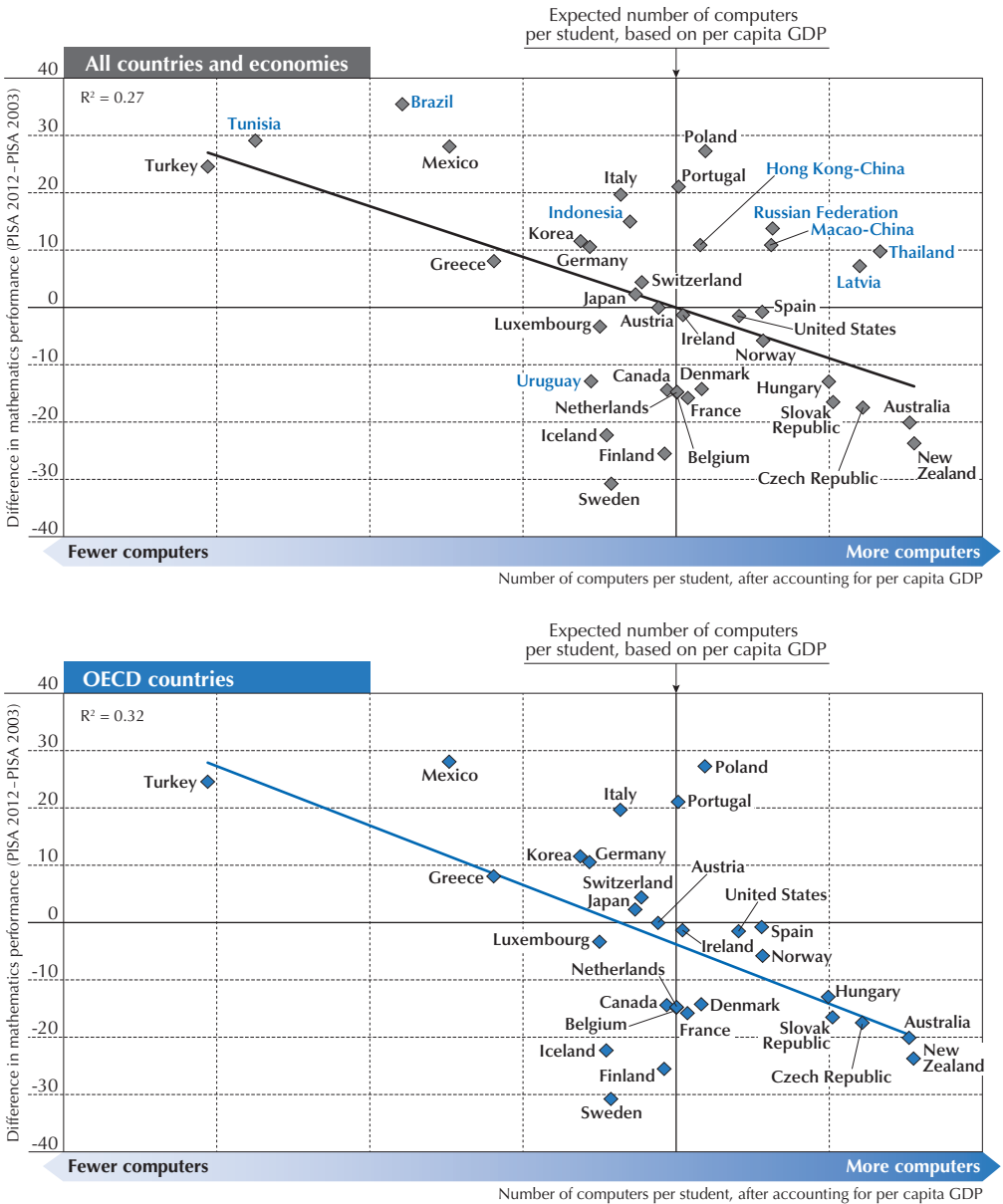**Source:** OECD, PISA 2012 Database, Table 6.1.
StatLink ᵃˢ⁴ http://dx.doi.org/10.1787/888933253256

STUDENTS, COMPUTERS AND LEARNING: MAKING THE CONNECTION

■ Figure 6.3 ■

Trends in mathematics performance and number of computers in schools

Expected number of computers
per student, based on per capita GDP

All countries and economies

$R^2 = 0.27$

Difference in mathematics performance (PISA 2012 – PISA 2003)

Tunisia · Brazil · Turkey · Mexico · Italy · Poland · Portugal · Hong Kong-China · Indonesia · Korea · Germany · Russian Federation · Macao-China · Thailand · Greece · Switzerland · Latvia · Japan · Spain · Austria · United States · Luxembourg · Ireland · Norway · Uruguay · Canada · Denmark · Hungary · Netherlands · France · Slovak Republic · Australia · Iceland · Belgium · Finland · New Zealand · Czech Republic · Sweden

Fewer computers   More computers

Number of computers per student, after accounting for per capita GDP

Expected number of computers
per student, based on per capita GDP

OECD countries

$R^2 = 0.32$

Difference in mathematics performance (PISA 2012 – PISA 2003)

Turkey · Mexico · Italy · Poland · Portugal · Korea · Germany · Austria · Greece · Switzerland · United States · Japan · Luxembourg · Spain · Ireland · Norway · Netherlands · Canada · Denmark · Hungary · Belgium · France · Australia · Slovak Republic · New Zealand · Iceland · Czech Republic · Finland · Sweden

Fewer computers   More computers

Number of computers per student, after accounting for per capita GDP

Note: The horizontal axis reports residuals from a regression of the student-computer ratio on per capita GDP (both variables are measured in logarithms).
Source: OECD, PISA 2012 Database, Table I.2.3b (OECD, 2014), Table IV.3.2 (OECD, 2013) and Table 2.11.
StatLink 🔗📑 http://dx.doi.org/10.1787/888933253262

■ Figure 6.4 ■

**Trends in reading performance and proportion of students
who frequently browse the Internet for schoolwork at school**
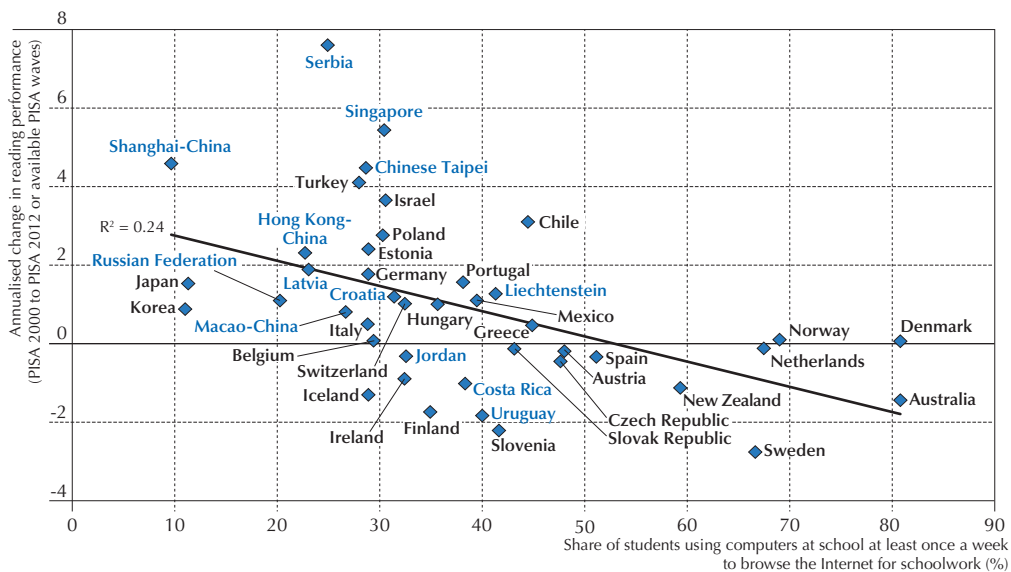
Notes: The annualised change is the average annual change in PISA score points. It is calculated taking into account all of a country's and economy's participation in PISA.
Source: OECD, PISA 2012 Database, Table I.4.3b (OECD, 2014) and Table 2.1.
StatLink ⌗ http://dx.doi.org/10.1787/888933253271

In Chapter 4, this index was shown to account for a significant part of the variation in digital reading performance across countries of similar performance in print reading. Among the countries/economies where the quality of students' online navigation is highest, Australia has one of the largest shares of students who frequently browse the Internet at school for schoolwork, Korea one of the smallest, and Singapore an average share (Tables 2.1 and 4.1).

HOW PERFORMANCE IS ASSOCIATED WITH STUDENTS' USE OF ICT FOR SCHOOL

This section compares students within countries/economies, focusing particularly on performance in digital reading and computer-based mathematics, where, in theory, a stronger relationship with exposure to computers can be expected. Do students perform better in digital reading when they read on line more frequently for schoolwork? What is the relationship between students' use of computers during mathematics lessons and their ability to use computers for solving mathematics problems?

When interpreting these relationships, it is important to bear in mind two aspects of the PISA data (see Box 6.1). First, students reported on their use of computers during the current school year, but their performance also depends – and probably to a larger extent – on the learning opportunities and exposure to computers of past school years. In some countries, students who take the PISA test have been in their current school and grade for less than three months. Thus, in PISA data, even frequent use of computers at school might correspond to only short exposures.

Second, both the current level of performance and the current level of computer use might be the consequence of past performance levels. In most systems, 15-year-old students are either no longer in comprehensive schools or are streamed or grouped by ability in mathematics lessons. Variations in the use of computers might relate to the track or ability group of students. In other words, users and non-users might be very different from each other to start with, in terms of their aptitude, behaviour and disposition towards learning and school.

Analyses discussed in this section account for differences in socio-economic status across students and schools, but cannot account for past performance levels and for several other important determinants of students' exposure to computers at school.

Use of computers at school

The *index of ICT use at school* measures how frequently students engage in a variety of activities, such as browsing the Internet at school, using e-mail at school, chatting on line at school, and using computers for practice and drilling in foreign-language classes. Higher values of this index correspond to more frequent and more varied uses.

Figure 6.5 (left panel) shows that students who make slightly below-average use of computers at school have the highest performance in digital reading. Overall, the relationship is graphically illustrated by a hill shape, which suggests that limited use of computers at school may be better than no use at all, but levels of computer use above the current OECD average are associated with significantly poorer results.

■ Figure 6.5 ■
Students' skills in reading, by index of ICT use at school
OECD average relationship, after accounting for the socio-economic status of students and schools
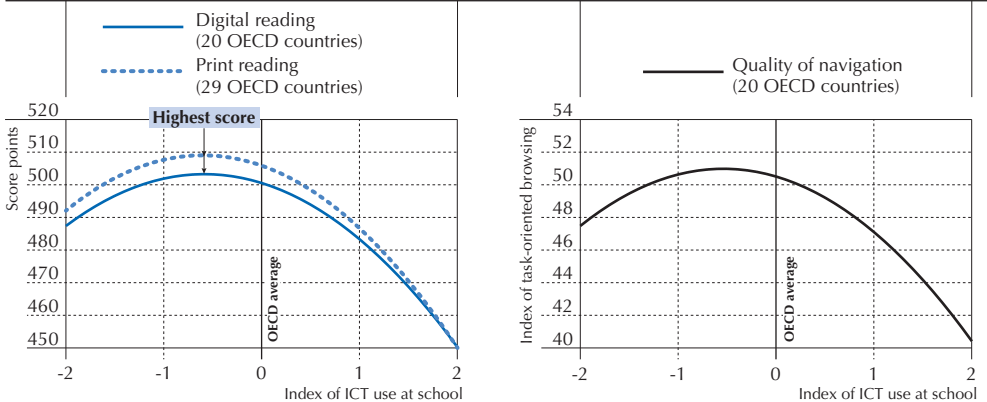
Notes: The lines represent the predicted values of the respective outcome variable, at varying levels of the *index of ICT use at school,* for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.
Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).
Source: OECD, PISA 2012 Database, Table 6.2.
StatLink 🖉 http://dx.doi.org/10.1787/888933253280

Figure 6.5 also shows that the relationship between computer use and performance is similar across digital and print reading; this suggests that even specific online reading skills do not benefit from high levels of computer use at school. This is confirmed by the right-hand panel, which relates the *index of task-oriented browsing* – an indicator of students' navigation and evaluation skills in online texts – to the *index of ICT use at school*. Even such specific online reading skills do not appear to benefit from more intensive use of computers at school.

Overall, using computers at school does not seem to confer a specific advantage in online reading. In detail, however, the relationship between performance and the frequency of use varies across activities.

The decline in performance associated with greater frequency of certain activities, such as chatting on line at school and practicing and drilling, is particularly large (Figure 6.6). Students who frequently engage in these activities may be missing out on other more effective learning activities. Students who never or only very rarely engage in these activities have the highest performance.

In contrast, for browsing the Internet or using e-mail, the relationship with reading skills becomes negative only when the frequency increases beyond "once or twice a week" (Figure 6.6). Thus, encouraging students to read on line, in moderation, may have positive effects on reading more generally. Teachers who offer a diverse range of materials to read can promote engagement with reading, particularly among boys (OECD, 2015). In 16 out of 25 countries/economies with available data, students who browse the Internet at school once or twice a month score above students who never do so on the PISA digital reading scale. In addition, the highest quality of navigation is attained by students who reported browsing the Internet at school "once or twice a week", suggesting that practice with online navigation in a school setting can be particularly important for specific skills related to online reading (Table 6.3c).

There are also significant differences across countries (Table 6.2, and Tables 6.3a through 6.3i). In Australia, in particular, more frequent browsing of the Internet at school – even the most frequent browsing – is associated with gains in digital reading skills. Australia is among the countries where students use computers at school the most.

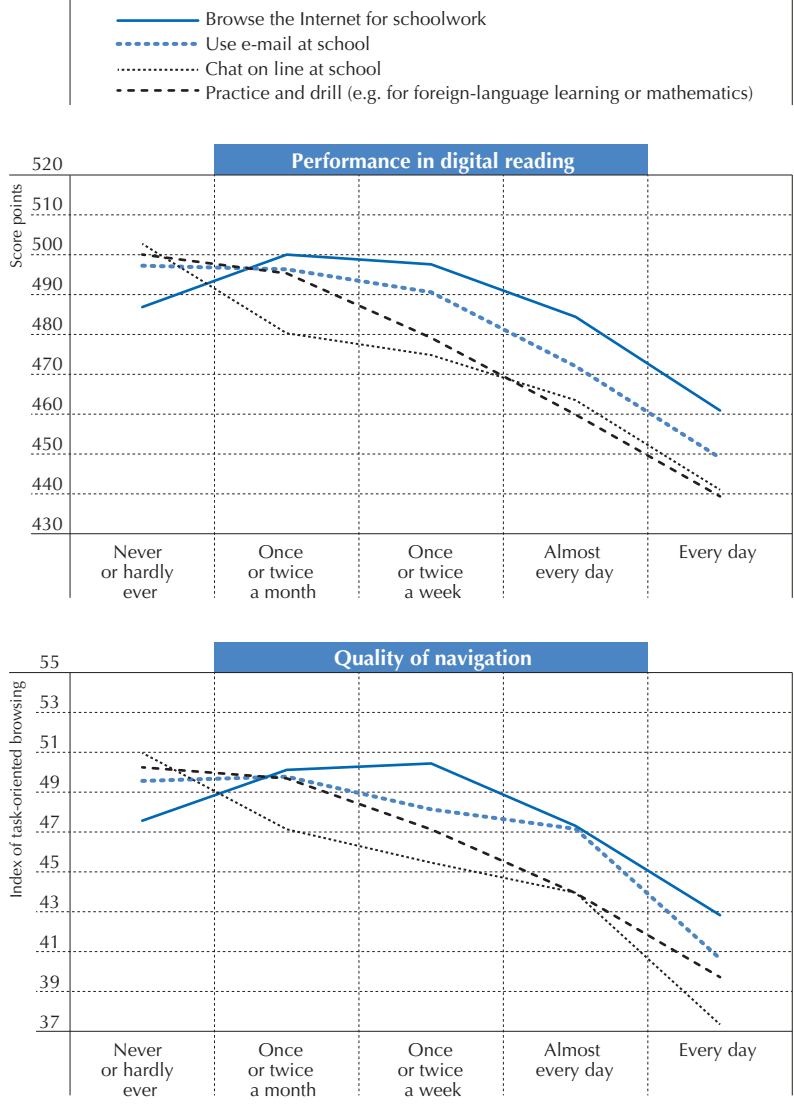## Use of computers in mathematics lessons

The *index of computer use in mathematics lessons* measures whether teachers or students use computers during mathematics lessons, and for which tasks. Higher values on this index correspond to more mathematics tasks being performed with computers, particularly by students.

Across OECD countries, students who do not use computers in mathematics lessons tend to perform better in the paper-based and the computer-based assessment of mathematics (Figures 6.7 and 6.8). This may reflect, to a large extent, the fact that advanced mathematics classes rely less on computers than more applied mathematics classes. However, even the ability to use computers as a mathematical tool – a skill that is only assessed in the computer-based assessment of mathematics – appears to benefit little from greater use of computers in mathematics classes, as shown in the right panel of Figure 6.7.

■ Figure 6.6 ■

Frequency of computer use at school and digital reading skills

*OECD average relationship, after accounting for the socio-economic status of students and schools*

——— Browse the Internet for schoolwork
········ Use e-mail at school
··········· Chat on line at school
– – – – Practice and drill (e.g. for foreign-language learning or mathematics)

Performance in digital reading

Quality of navigation

Notes: The charts plot the predicted values of the respective outcome variables for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.
Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).
Source: OECD, PISA 2012 Database, Tables 6.3a, b, c and g.
StatLink 🔗 http://dx.doi.org/10.1787/888933253296

■ Figure 6.7 ■

Performance in computer-based and paper-based mathematics, by index of computer use in mathematics lessons

OECD average relationship, after accounting for the socio-economic status of students and schools
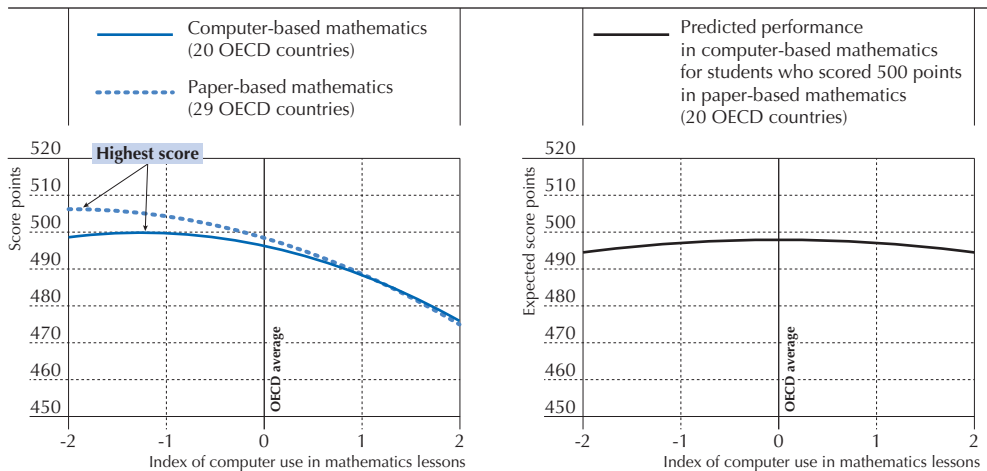
Notes: The lines represent the predicted values of the respective outcome variable, at varying levels of the *index of computer use in mathematics lessons,* for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.
Source: OECD, PISA 2012 Database, Table 6.4.
StatLink ⌦ http://dx.doi.org/10.1787/888933253302

Irrespective of the specific tasks involved, students who do not use computers in mathematics lessons perform better in mathematics assessments than students who do use computers in their mathematics lesson, after accounting for differences in socio-economic status (Figure 6.8).

There are, however, exceptions to this negative relationship. In Belgium, Denmark and Norway, there is a positive association between computer use in mathematics lessons and performance in the computer-based assessment of mathematics, particularly when the comparison accounts for differences in students' socio-economic status and in schools' socio-economic profile. Students who use computers during mathematics lessons tend to score higher than students who do not (Table 6.4, and Tables 6.5a through 6.5g). Denmark and Norway, too, are among the countries where students use computers at school the most.

Use of computers outside of school for schoolwork

The relationship between reading skills and using computers for schoolwork outside of school is, at first glance, similar to the relationship between reading skills and using computers for schoolwork at school. The *index of ICT use outside of school for schoolwork* measures how frequently students do homework on computers, browse the Internet for schoolwork, use e-mail for communications related to school, visit the school website, and/or upload or download materials on it. Higher values of this index correspond to more frequent and more varied uses.

■ Figure 6.8 ■
Computer use in mathematics lessons and performance in computer-based mathematics
OECD average relationship, after accounting for the socio-economic status of students and schools

———— Enter data on a spreadsheet
••••••• Construct geometrical figures
·········· Draw the graph of a function
– – – – Calculate with numbers

Performance in computer-based mathematics

Predicted performance in computer-based mathematics for students who scored 500 points in paper-based mathematics
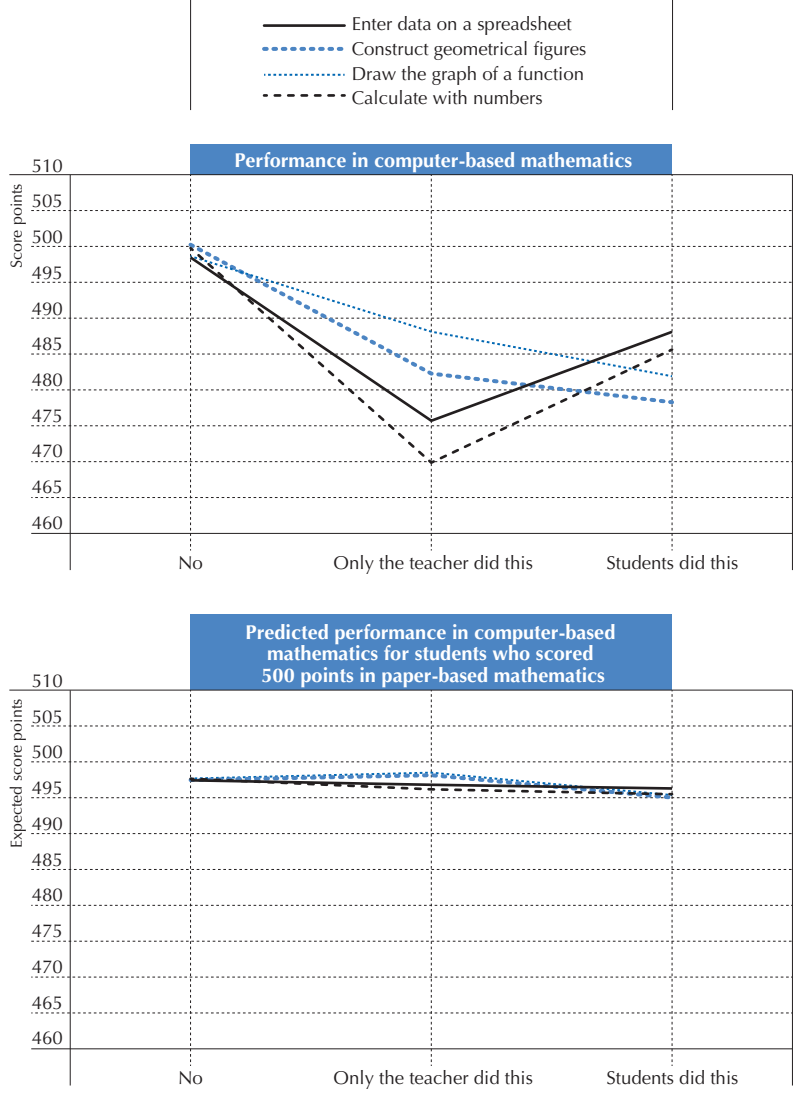
Notes: The top chart plots the predicted values of performance in computer-based mathematics for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero. The bottom chart plots the predicted values of performance in computer-based mathematics for students who scored 500 points in paper-based mathematics, have a value of zero on the index, and are in schools where the average value of ESCS is zero.
Source: OECD, PISA 2012 Database, Tables 6.5a, b, c and d.
StatLink 🔗📥 http://dx.doi.org/10.1787/888933253318

Students who use computers for schoolwork outside of school to a moderate degree perform best in both digital and print reading – higher than students who never use computers at all. When computer use increases beyond the OECD average, however, the relationship turns negative. This hill-shaped relationship is also observed when considering the quality of students' navigation (*index of task-oriented browsing*) (Figure 6.9).

■ Figure 6.9 ■

Students' skills in reading, by index of ICT use outside of school for schoolwork

OECD average relationship, after accounting for the socio-economic status of students and schools
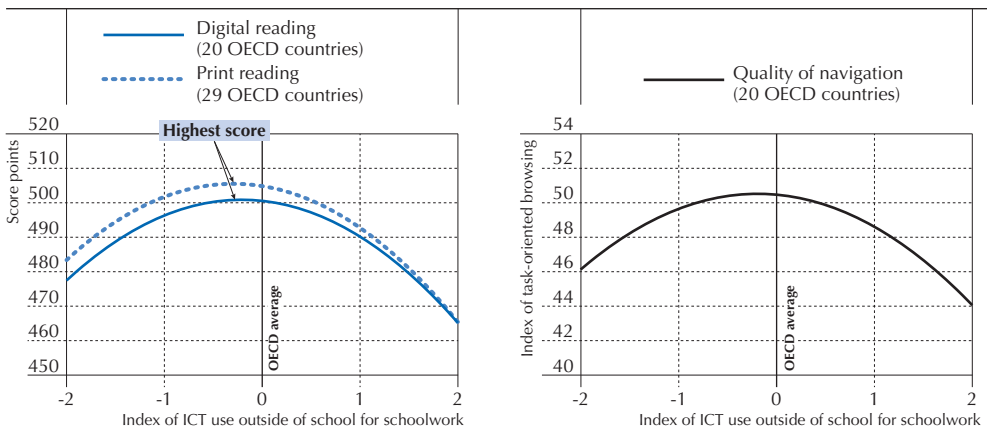
Notes: The lines represent the predicted values of the respective outcome variable, at varying levels of the *index of ICT use outside of school for schoolwork*, for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.
Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).
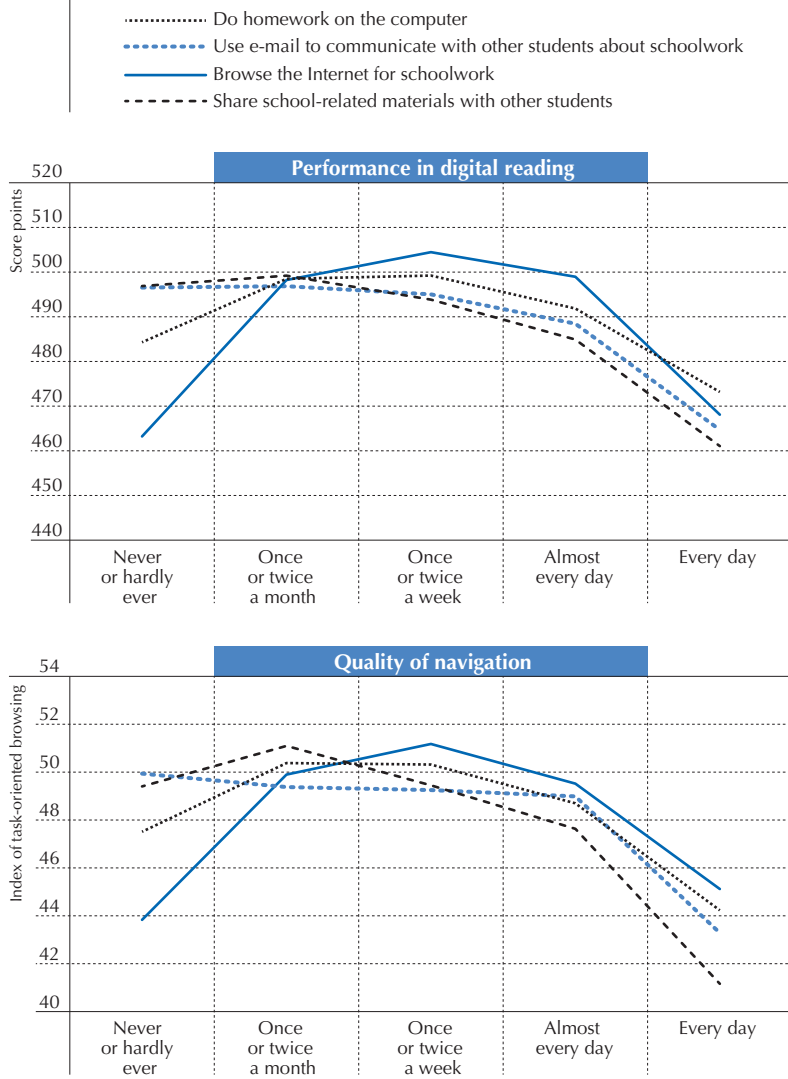**Source:** OECD, PISA 2012 Database, Table 6.6.
StatLink ⌘☞ http://dx.doi.org/10.1787/888933253329

The two homework activities listed in the ICT familiarity questionnaire (doing homework on computers, and browsing the Internet for schoolwork) show a similar hill-shaped relationship with performance. Students who never do these activities on computers, and students who do them every day, are the two groups with the lowest performance in the assessment of digital reading. When considering communication activities among students and with teachers, such as using e-mail to communicate with other students, there is no difference in average performance between students who never use a computer for these activities, and students who do so up to once or twice a week (Figure 6.10).

When interpreting these results, it is important to bear in mind that what students do when they are free to choose how to spend their time depends on their skills (what they are able to do) and their dispositions towards learning more generally. For example, the group of students who rarely use computers for doing homework outside of school includes those students who rarely do any homework outside of school, irrespective of whether they do so with computers or not.

■ Figure 6.10 ■

Frequency of computer use outside of school for schoolwork and digital reading skills

OECD average relationship, after accounting for the socio-economic status of students and schools

- ·············· Do homework on the computer
- ··········· Use e-mail to communicate with other students about schoolwork
- ——— Browse the Internet for schoolwork
- – – – – Share school-related materials with other students

Performance in digital reading

Score points

520
510
500
490
480
470
460
450
440

Never or hardly ever | Once or twice a month | Once or twice a week | Almost every day | Every day

Quality of navigation

Index of task-oriented browsing

54
52
50
48
46
44
42
40

Never or hardly ever | Once or twice a month | Once or twice a week | Almost every day | Every day

Notes: The charts plot the predicted values of the respective outcome variables for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.
Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).
Source: OECD, PISA 2012 Database, Tables 6.7a, b, f and g.
StatLink ⟨⟩ http://dx.doi.org/10.1787/888933253338

The relationship between doing homework on computers and performance might reflect students' engagement with school, in general, rather than their use of computers for school, in particular.

USE OF COMPUTERS AT HOME FOR LEISURE AND DIGITAL READING PERFORMANCE
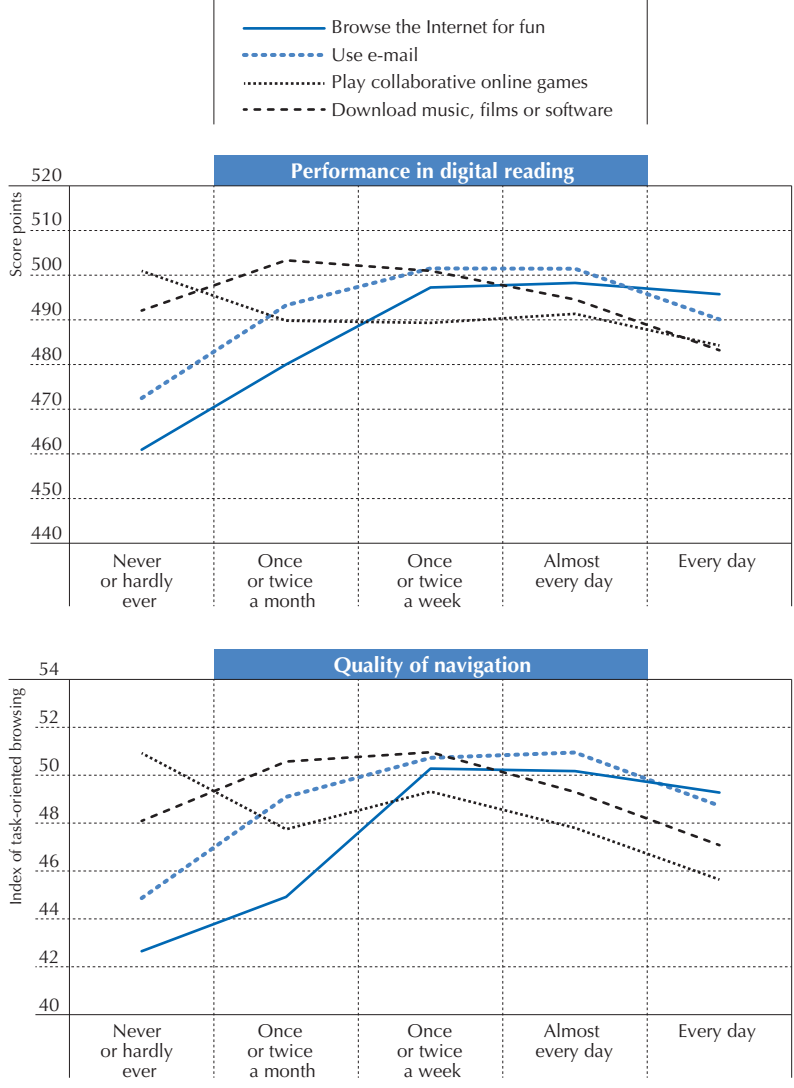
Students use computers at home for playing games, to remain in contact with friends, and for all sorts of leisure activities, such as downloading music, reading news, or simply browsing the Internet for fun. The frequency and variety of leisure activities in which students engage when using computers at home is summarised in an *index of ICT use outside of school for leisure*.

Figure 6.11 shows the hill-shaped relationship between the uses of computers at home for leisure and digital reading performance. Moderate users tend to perform better than both intensive users and rare users. The figure also shows a similar, hill-shaped relationship with print reading. In this latter case, however, rare users perform better than intensive users (those with the highest values on this index).

■ Figure 6.11 ■
Students' skills in reading, by index of ICT use outside of school for leisure
OECD average, after accounting for the socio-economic status of students and schools
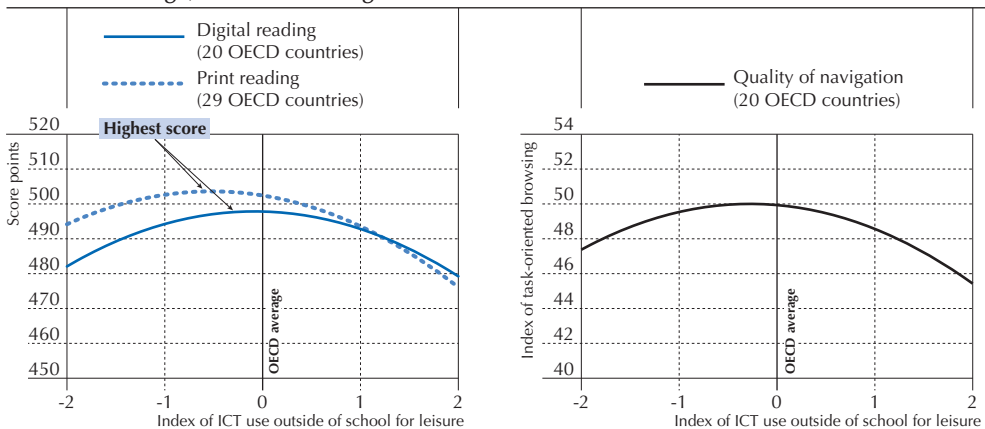
Notes: The lines represent the predicted values of the respective outcome variable, at varying levels of the *index of ICT use outside of school for leisure,* for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.
Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).
Source: OECD, PISA 2012 Database, Table 6.8.
StatLink ⌨⬛ http://dx.doi.org/10.1787/888933253343

Students who use computers most intensely differ in many ways from students who use computers rarely, if at all. Computer use, itself, may be the result, rather than the cause, of different levels of digital skills. For these reasons, it is not possible to interpret these associations as simple cause-effect relationships. Nevertheless, these patterns indicate that it is not necessary to use computers frequently to perform well in digital reading.

■ Figure 6.12 ■

Frequency of ICT use outside of school for leisure and digital reading skills

OECD average relationship, after accounting for the socio-economic status of students and schools

——— Browse the Internet for fun
·········· Use e-mail
············ Play collaborative online games
‑ ‑ ‑ ‑ ‑ Download music, films or software

Notes: The charts plot the predicted values of the respective outcome variables for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.
Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).
Source: OECD, PISA 2012 Database, Tables 6.9b, c, f and i.
StatLink ㎤ http://dx.doi.org/10.1787/888933253359

In fact, Figure 6.12 shows that the relationship between leisure activities on computers and performance in digital reading varies depending on the specific activity. Some activities, such as browsing the Internet for fun or using e-mail, are more positively related to proficiency in online reading than others, such as playing collaborative games on line or downloading music or films from the Internet. Better online readers do more of the former, and less of the latter.

These differences across different activities must be interpreted in light of the fact that students select their leisure activities, in part, based on what they enjoy most; and this, in turn, depends on how well they are able to handle the task. Students who read more tend to be better readers; in turn, better readers are likely to feel rewarded by reading more. Reading engagement and reading proficiency sustain each other in a reciprocal relationship.

RESEARCH EVIDENCE ON THE IMPACT OF COMPUTER USE ON STUDENT PERFORMANCE

Overall, the most frequent pattern that emerges in PISA data when computer use is related to students' skills is a weak or sometimes negative association between investment in ICT use and performance. While the correlational nature of this finding makes it difficult to draw guidance for policy from it, the finding is remarkably similar to the emerging consensus in the research literature, based on studies that use more rigorously designed evaluations.

Several studies have assessed the impact on education outcomes of allocating more resources for ICT in schools. Most recent research in this field has been conducted using "natural experiments", whereby the given reality of the situation creates a control group that can be compared to the "treated" group, which in this case represents the schools that receive the additional resources. The majority of these studies finds that such policies result in greater computer use in "treated" schools, but only few studies find positive effects on education outcomes, even when the new resources did not displace other investments (Bulman and Fairlie, forthcoming). Evidence resulting from such "natural experiments" in Israel (Angrist and Lavy, 2002), the Netherlands (Leuven et al., 2007), California (Goolsbee and Guryan, 2006) and Peru (Cristia, Czerwonko and Garofalo, 2014) agrees with the finding of limited, and sometimes negative, effects on traditional performance indicators, such as test scores, grades in national examinations, and incidence of dropout.

Few studies are based on controlled experiments, whereby treatment and control groups are created by a random draw. A randomised evaluation of the "Computers for Education" programme in Colombia (Barrera-Osorio and Linden, 2009) finds limited effects on learning, but also finds that additional computers did not translate into increased use of computers for instruction.

As an exception to these findings, Machin, McNally and Silva (2007) report performance gains from increased funding for ICT equipment among primary schools in England. These authors use a change in the rules governing the allocation of funds across local education authorities, around the year 2000, to compare schools (or rather, local education authorities) that gained additional funds under the new rules to those whose resources decreased or remained constant.

Other studies have assessed the impact of specific uses of ICT on education outcomes. Experimental evaluations of specific uses of computers for instructional purposes – such as educational software – tend to report positive results more often (Bulman and Fairlie, forthcoming). However, to interpret

these findings it is crucial to determine whether the introduction of computer-assisted instruction increases learning time overall or displaces other learning activities.

In his review of the effectiveness of computer-assisted instruction, based on 81 meta-analyses of research published over the past 30 years, Hattie (2013) finds that the effect on learning is neither larger nor smaller than the typical effect found from other well-intentioned teaching interventions, on average. As a result, if computer use replaces similarly effective teaching activities, the net effect may be zero.

Furthermore, the specific uses promoted in the context of experimental evaluation studies may be better than the average uses that "normal" teachers promote in their classrooms. In their analysis of TIMSS data, which links, for the same student, differences in computer use across subjects (mathematics and science) to differences in performance, Falck, Mang and Woessmann (2015) find that mathematics results are unrelated to computer use, while science results are positively related to certain uses ("looking up ideas and information") and negatively related to others ("practicing skills and procedures").

Effects, indeed, are likely to vary depending on the context and the specific uses. In their assessment of the literature on computer-assisted instruction, Hattie and Yates (2013) report stronger effects when computers were supplementing traditional teaching, rather than seen as its alternative. According to these authors, positive effects were achieved in interventions that followed the same principles of learning that apply for traditional teaching as well: computers were particularly effective when used to extend study time and practice, when used to allow students to assume control over the learning situation (e.g. by individualising the pace with which new material is introduced), and when used to support collaborative learning.

Rigorous experimental evidence on the effect of home computer use on students' performance in school is more limited. Three recently published experiments report mixed evidence. Exploiting a sharp discontinuity in eligibility rules for a computer-vouchers programme for families with school-aged children in Romania, Malamud and Pop-Eleches (2011) find mixed evidence on impacts, with some outcomes, such as school grades, deteriorating for the eligible students, and other outcomes, such as computer skills and cognitive skills measured with Raven's progressive matrices, improving. In a randomised trial in California, where free computers where given to students in grades 6-10 who previously had none, no effects were found on grades, test scores, credits earned, or engagement with school (Fairlie and Robinson, 2013). Finally, in a randomised trial in Peru, about 1 000 primary school children selected by a lottery received a free laptop computer for home use. Five months after receiving the computer, these children reported greater use of computers overall and were more proficient in using them than non-recipients. No effects were found however on reading and mathematics scores, on cognitive skills, and on more general ICT proficiency; while teachers reported that recipients of free computers exerted less effort at school compared to non-recipients (Beuermann et al., 2015).

Overall, the evidence from PISA, as well as from more rigorously designed evaluations, suggests that solely increasing access to computers for students, at home or at school, is unlikely to result in significant improvements in education outcomes. Furthermore, both PISA data and the research evidence concur on the finding that the positive effects of computer use are specific – limited to certain outcomes, and to certain uses of computers.
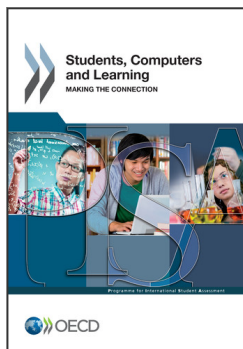
Chapter 6 tables are available on line at http://dx.doi.org/10.1787/edu-data-en.

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.

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