Organisation for Economic Co-operation and Development

EDU/EDPC/SR/RD(2020)2

For Official Use

English - Or. English

8 June 2020

DIRECTORATE FOR EDUCATION AND SKILLS
EDUCATION POLICY COMMITTEE

Cancels & replaces the same document of 4 June 2020

ICT resources in school education: What do we know from OECD work?

Draft

Virtual meeting, 22-23 June 2020, 7th Meeting of the Group of National Experts on School Resources and 2nd meeting of the OECD Teachers' Professional Learning Study

The work on this paper was conducted in the context of the OECD Review of Policies to Improve the Effectiveness of Resource Use in Schools (School Resources Review). This draft was prepared for discussion at the 7th meeting of the Group of National Experts on School Resources on 22 June 2020.

Delegates are invited to:

- DISCUSS the paper and PROVIDE feedback on its content.

Contacts:
Deborah NUSCHE, Senior Analyst, deborah.nusche@oecd.org (+(33-1) 45 24 78 01)
Andreea MINEA-PIC, Analyst, andreea.minea@oecd.org (+(33-1) 45 24 92 78)

JT03462734

Table of contents

Tables

Figures

Boxes

ICT resources in school education: what do we know from OECD work?

Digital technologies are a key resource for OECD school systems, holding immense promise for education and skills development. They provide access to countless learning resources, can transform teaching and learning practices in schools, and improve decision-making in education systems thanks to novel data collection and analysis. As the Covid-19 crisis has led to school closures in most countries around the globe (UNESCO, 2020[1]), governments, school leaders and teachers have turned to digital tools to support the continuity of student learning and provide alternative options for teacher professional development.

Digital technologies can enter initial education systems at different levels:

- **as objectives of learning** for students, for instance when they are part of the curriculum (e.g. ICT classes, computer science, computational thinking); or for teachers, for instance when they are part of teaching standards or competency frameworks;
- **as tools to support student learning**, inside the classroom, at school or at home;
- **as tools to support teachers**, whether for teaching or non-teaching activities, inside the classroom and outside the classroom (e.g. preparing lessons, assessment, communicating with parents/students);
- **as tools to support the management of schools and education systems** (e.g. for school leaders, system leaders).

This paper provides an overview of existing OECD work on digital technologies in school education. It may provide a basis to develop an overarching conceptual framework for the OECD to analyse policies to improve the effectiveness of technology use in school systems. It puts forward insights from OECD international surveys and research, among which PISA, TALIS, the Skills Outlook, CERI work on teacher knowledge and smart data in schools. It also provides considerations on gap areas in existing analyses and main topics or questions that could be explored from a resource policy perspective in the 2021-22 biennium. Annexe A provides an overview of OECD projects with a focus on digital technologies in schools are currently ongoing or have been recently completed.

What do we know from previous OECD work?

Previous OECD research and data collection on digital technologies in education have mostly revolved around the role of digital tools for student learning at the classroom level, as part of teaching and learning activities. The access to and use of digital technologies in school education (as tools for learning, teaching but also as objectives of learning) have been at the core of most existing analyses. A different, though relatively smaller, strand of work has revolved around the question of policies to seize the benefits of the digital transformation in education systems, with a particular focus on the development of teachers' digital competence. However, many gaps remain with respect to cross-cutting issues related to funding, regulations (at different levels), as well as more system-level policies related to ICT as a resource in education systems.

Digital technologies as objectives for learning

ICT as an objective of learning for students

To thrive in a digital world, students need to be equipped with a good mix of skills, including digital competence. Having a good level of literacy, numeracy and problem-solving skills in technology-rich environments enables individuals to move from elementary uses of Internet to more diversified and complex uses that allow them to make the most of digital technologies. Evidence from the Skills Outlook 2019, based on desk-based research, shows that adapting the school curriculum to changing skills requirements in order to help develop 21st century skills (e.g. creativity, critical thinking, digital competence) from an early age, has been one of the strategies used in OECD countries to create strong foundations for lifelong learning and support individuals in adapting to evolving skills requirements (OECD, 2019[2]).

Given the rapid pace of technological evolution, the definition of digital competence has been constantly evolving, reflecting that individuals need more than specialised digital skills related to the use of software or learning specific coding languages. While the development of digital competence has initially been the objective of stand-alone ICT classes, evidence from the Skills Outlook 2019 based on desk-based research suggests the countries are increasingly adopting a more comprehensive approach that integrates ICT across all curricular areas (OECD, 2019[2]). The focus is thus progressively shifting towards a mix of skills including, among others, the capacity to understand the nature of algorithms, to make critical uses of digital technologies, be able to collaborate to solve problems using such technologies, and be resilient on line.

Evidence from 22 education systems that responded to the 21st Century Children Policy Questionnaire shows that many systems put an emphasis on teaching both “hard” and “soft” digital skills, including critical information, social and creative skills as well as basic operational skills (Burns and Gottschalk, 2019[3]). Most education systems teach digital skills at the secondary level and then at the primary level, while less than 20% of them focus on such skills in early childhood/pre-primary education. In line with other frameworks of digital competence (OECD, 2019[2]), the PISA 2021 ICT framework puts forward an approach to ICT competencies based on five competency areas: accessing, evaluating and managing information and data; sharing information and communicating; transforming and creating digital content; problem solving in a digital context and computational thinking; appropriate use of ICT (online security, safety and risk awareness, skills) (OECD, 2019[4]).

ICT as an objective of learning for teachers

As digital tools progressively enter schools and classrooms, understanding teachers’ knowledge about technology integration for teaching is crucial to provide the required support to help develop teachers’ digital competence (Xiong, 2020[5]). To tackle the need for teachers to enhance their ICT skills for instructional use (or application), OECD countries have relied on a range of policies, including the development of national plans to promote this goal, compulsory training, national accreditation standards or national certification for teachers (OECD, 2019[2]).

The emerging technological, pedagogical and content knowledge (TPACK) framework provides an opportunity to investigate teachers’ knowledge of teaching with technology from a pedagogical perspective. TPACK is based on an “understanding of how technologies can be used in constructive ways to support teaching and student learning for a subject matter” (Mishra and Koehler, 2007). Teachers should not only master the use of technology, but they should be able to coordinate technology, pedagogy and subject matter in order to obtain the desired student learning outcomes (Xiong, 2020[5]).

While international surveys, such as PISA or TALIS, have focused on ICT-based practices in classrooms and teachers’ self-reported confidence about using ICT, less attention has been given to teachers’ knowledge of technology from a pedagogical perspective and on how such knowledge relates to teachers’ opportunities to learn (Xiong, 2020[5]). Previous empirical studies relying on TPACK to assess teachers’ knowledge have been confronted with a series of validity and reliability issues. However, the framework has the potential to be combined with more comprehensive theoretical frameworks, such as that of the OECD's Innovative Teaching for Effective Learning (ITEL) teacher knowledge survey (now under the TALIS umbrella), to better investigate teachers' knowledge about technology use in teaching (Xiong, 2020[5]).

Digital technologies as tools to support student learning

Average access and divides

Access to digital technologies in schools is extensive across OECD countries. Analyses based on PISA (2018) show that for every 15-year old student, there is almost one computer available at school for educational purposes and the computer-student ratio has largely increased since 2009 (Reimers and Schleicher, 2020[6]). Similarly, access to the Internet was widespread already in 2015, with 91% of students in OECD countries with available data in the PISA ICT questionnaire reporting to have access to Internet at school (Lorenceau, Marec and Mostafa, 2019[7]). At the same time, availability of ICT resources does not imply quality (e.g. computing capacity, bandwidth). The following sections will discuss further the quality and adequacy of digital technologies for learning.

As the Covid-19 crisis has led to the closure of schools in many countries, access to digital technologies at home has become critical to enable students to remain connected to their teachers and peers, and continue learning outside of the school premises. Connectivity at home in OECD countries has been on a steady rise in the last two decades: the share of students who have access to the Internet at home rose from 57% in 2003 to more than 92% in 2015, among the 40 countries with available data in these PISA rounds (Lorenceau, Marec and Mostafa, 2019[7]). In 2018, 96.5% of students in OECD countries reported having access to an Internet connection at home and 89% to a computer they could use for schoolwork.

Despite advances in connecting individuals and students in the last decades, divides in the access to digital technologies persist in a number of OECD countries. Students from socio-economic disadvantaged schools are less likely to have access to a computer for schoolwork and, in some countries, to benefit from an Internet connection at home. In Mexico, around 30% of students from disadvantaged schools have access to a computer or link to the Internet at home, in contrast to more than 90% of advantaged students (Reimers and Schleicher, 2020[6]). Sizeable socio-economic gaps in students' access to an Internet connection at home are also observed in Chile (22% gap in access between students from disadvantaged schools and those from advantaged ones), Colombia (60%) and Turkey (43%). Similarly, large gaps in access to a computer for schoolwork at home between students attending disadvantaged schools and those attending advantaged ones are observed in Colombia (58%), Japan (23%), Turkey (46%) and the United States (22%). In Mexico and Colombia, data from PISA (2015) showed that large inequalities in access to digital tools also persisted between students from rural and urban areas. Schools help narrow connectivity gaps in countries where socio-economic background or geography shape access to digital technologies at home (OECD, 2020[8]). However, as the COVID-19 crisis has led students to study from home, remaining gaps in access to digital technologies from home represent important obstacles to learning activities and risk leaving some students behind.

In addition, the digital divide no longer concerns only gaps in access to digital technologies. Increasingly, inequalities between individuals concern how they use digital tools and the benefits they can derive from their uses (OECD, 2019[2]; Burns and Gottschalk, 2019[3]). Many factors, including geography or socio-economic status, that explain inequalities in access, also lie behind gaps in the use of digital tools. Among them, skills play an important role in the evolution of digital divides. In European countries, lacking skills has become an ever-more important reason for not having Internet access. In addition, cognitive skills play a key role in how individuals participate in online activities (OECD, 2019[2]). Low-skilled students, similarly to adults, are more likely to use the Internet for recreational rather than instructional activities (van Deursen and van Dijk, 2014[9]).

At the same time, while differential access to technology raises equity-related issues, technology can also be equity-enhancing. Smart uses of digital technologies, such as those embodied in adaptive learning and enhanced personalisation of learning experiences, the larger access to an array of learning resources and equipment (e.g. through remote laboratories), or the use of Artificial Intelligence to accompany instruction with diagnosis and personalisation- hold great potential in terms of inclusion. Learning analytics[1] based on big data gathered thanks to navigation on line, social networks or networked devices and sensors also bring strong support to the development of more personalised learning experiences (OECD, 2019[10]). Digitalisation provides new opportunities for education systems to swift away from a "one-size-fits-all" teaching approach to personalised learning experiences that also allow identifying more easily students who are at risk of dropout while also assessing the effectiveness of a variety of teaching strategies (OECD, 2020[11]). Such innovative and smart uses of data and digital technologies provide pathways for more inclusive and high-quality learning experiences.

Types of digital tools

As digital technologies have developed and diversified at a fast pace, PISA rounds have progressively collected information on the availability of a wider variety of digital devices (e.g. laptops, e-Book readers, interactive whiteboards). The decrease in availability of desktop computers at home and at school has indeed been accompanied by a stark rise in the share of students reporting access to laptops or tablets (Lorenceau, Marec and Mostafa, 2019[7]; OECD, 2019[2]). Data from PISA 2018 show that in Denmark, Norway or Sweden, almost all computers available in school are portable (Reimers and Schleicher, 2020[6]). Similarly, many students are likely to have access to a smartphone or Internet-connected phone at home. Less than 5% of surveyed students in PISA (2018) reported lacking access to a cell-phone with Internet at home and among those with access, 92% of them reported using it.

At the same time, while using learning apps or going online for school –related work occasionally through a smartphone may be easy to do, connecting every day and for a long time to pursue learning activities is likely to be more demanding and tiresome for students. Without a computer for schoolwork or a larger device on which they can access the necessary tools and activities for learning, students who are expected to pursue longer learning activities relying only on a smartphone are likely to experience more difficulties in keeping up the pace. In the current Covid-19 context, the type of digital devices to which students have access at home has become of crucial importance.

Digital devices *per se* are only one facet and the first step to access an ever-increasing number of digital learning opportunities. Open education resources, educational software, MOOCs, learning apps or online platforms are a few examples of learning materials or tools students can rely upon. Collecting data on the diversity of resources now available for student learning has proven challenging, in the light of fast technological advances in the field. After a rise between 2003 and 2006, the share of students with access to educational software has stagnated across PISA countries with available data (Lorenceau, Marec and Mostafa, 2019[7]). In 2018, around half of 15-year-olds reported having access to educational software at home. These figures are also likely to reflect the development of more novel tools and opportunities for learning, available mostly on line. Access to many of the new digital resources for learning is thus largely dependent on the availability of an Internet connection, although their availability does not necessarily ensure that all students who have access are equally likely to use them (especially for learning activities).

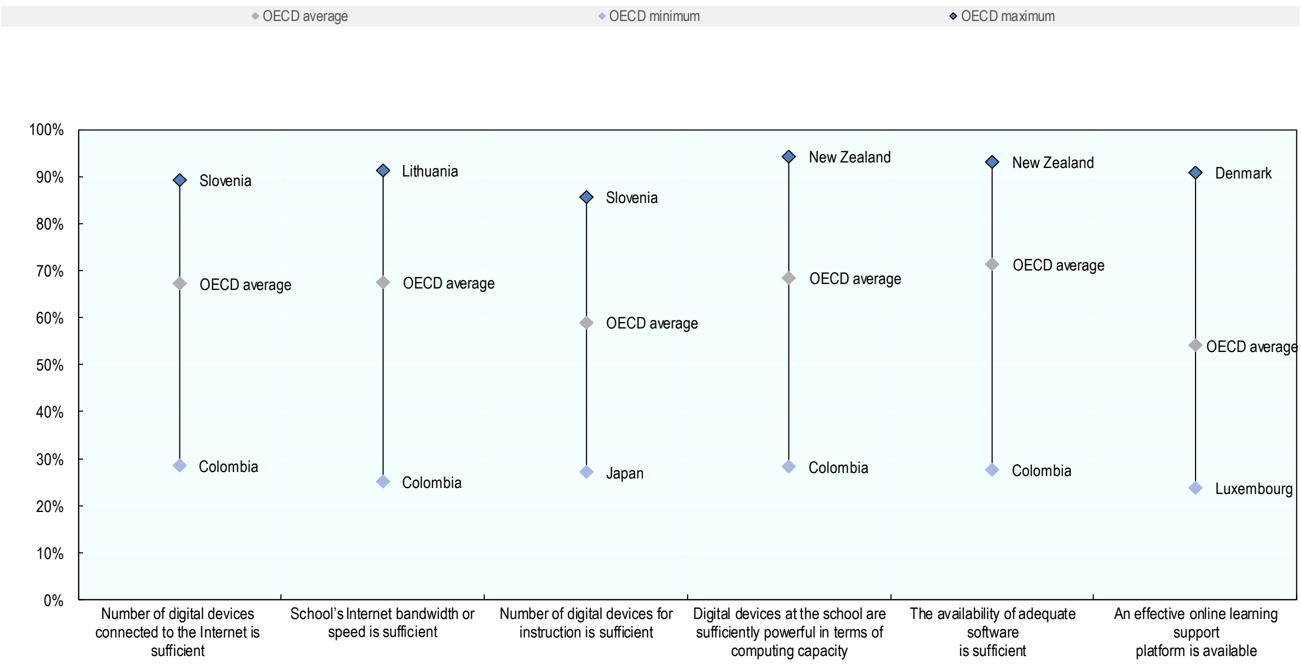
Quality of digital tools

Access and availability of ICT resources for learning at school do not necessarily imply quality and the latter has been rarely measured in a systematic way (Bulman and Fairlie, 2016[12]). If computers are old, educational software inadequate or the Internet connection slow, the mere availability of ICT resources is unlikely to be sufficient to support student learning. The same holds if there are not enough computers for students or computers are not easily available to students.

Data from PISA (2018) and TALIS (2018) provide evidence on the perceived shortages and inadequacy of digital technologies available for learning and teaching in schools. On average across OECD countries, more than two thirds of 15-year-olds are in schools where the principal reports that digital devices are sufficiently powerful in terms of computing capacity (Figure 1). A similar share are in schools where Internet bandwidth or speed are judged to be sufficient.

Figure 1. Adequacy of digital technologies in schools

Percentage of students in schools whose principal agreed or strongly agreed with the different statements about the school's capacity to enhance learning and teaching using digital devices



Source: OECD calculations based on PISA (2018).

These figures hide however between and within-countries disparities. Around 90% of students in Denmark, Lithuania or Slovenia are in schools where principals report that the school's Internet bandwidth or speed is sufficient, in contrast to less than 30% in Colombia. Perceptions of higher shortages or inadequacy of digital technologies are also more recurrent among students from disadvantaged schools. In Colombia, Mexico and Spain, the gap between students from disadvantaged schools and those from advantaged schools goes up to more than 40 percentage points when it comes to the extent to which digital devices at school are sufficiently powerful in terms of computing capacity.

Volume V of PISA (2018) will examine in greater detail disparities in online learning opportunities and in particular, inequities in shortages of educational materials and ICT resources across different types of schools (rural vs. urban, disadvantaged vs. advantaged). On the measurement side, the PISA (2021) ICT framework seeks to go a step further in examining the quality of ICT resources available in schools across OECD countries. In particular, it aims to examine students' perceptions through three main quality-related dimensions: the technical capacity of ICT resources (e.g. type of Internet connection- broadband, fibre, etc.; modalities of connection- wireless or wired; corresponding bandwidths available per student), the modality of access to ICTs (e.g. whether digital resources are easily available within the classroom) and the relevance of ICTs and guidance on how to use them (e.g. whether students find digital learning resources engaging) (OECD, 2019[4]).

Students' use of technologies (level, frequency and outcomes)

The use of digital devices available in schools is not widespread in all OECD countries with available data in PISA (2018). On average, around 72% of 15-year-olds report using a desktop computer/ laptop /tablet that is available for them at school, a share relatively stable since 2009 (OECD, 2015[13]; OECD, 2019[2]). Around 9 out of 10 students report using computers available in schools in Australia, Finland and Sweden, in contrast to less than half of students in Poland and Turkey.

While the level of use of desktop computers / laptops / tablets available in schools has remained relatively stable, the frequency of digital devices uses at school has been on the rise PISA collects information on the frequency with which students make a variety of uses of digital devices at school, including chatting, browsing the Internet for school information, doing homework or group work on a computer, irrespective of the device on which the use is performed. The overall increase in the share of students making frequent uses of digital devices at school has been triggered by the higher frequency of chatting on line. In 2015, 42% of 15-year-olds from OECD countries with available data reported that they chatted at school at least once per week, in contrast to less than 20% in 2012 (OECD, 2019[2]). The use of smartphones at school is likely to drive some of the observed patterns. Indeed, the ICT questionnaire in PISA 2015, similarly to previous PISA rounds, did not account for the place where digital devices uses took place at school (inside or outside the classroom), the amount of time devoted to them, their integration in teaching activities or on the contrary their occurrence without teacher supervision.

At home, students are exposed to ICTs at increasingly younger ages and spend an ever larger amount of time going on line or using digital devices. In 2015, 18% of students across OECD countries had access the Internet for the first time before being six-years-old. Young children (under 4) access the Internet for a variety of reasons (e.g. using communication apps to keep in touch with family members, watch television, videos or cartoons) and relying on different devices, although they tend to prefer touchscreen devices. These patterns also reflect a progressive narrowing of the digital divide in terms of access. In 2018, on average across OECD countries with available data in the PISA ICT questionnaire, students spent around 3 hours using the Internet outside of school on weekdays and around 3.5 hours on line on weekend days. The amount of time spent on line has thus increased by more than one hour per day, for both weekdays and weekend days, in comparison to 2012 (OECD, 2019[14]). Data from PISA (2015) showed that students tend to use digital devices at home with higher frequency for leisure rather than schoolwork activities (OECD, 2020[8]).

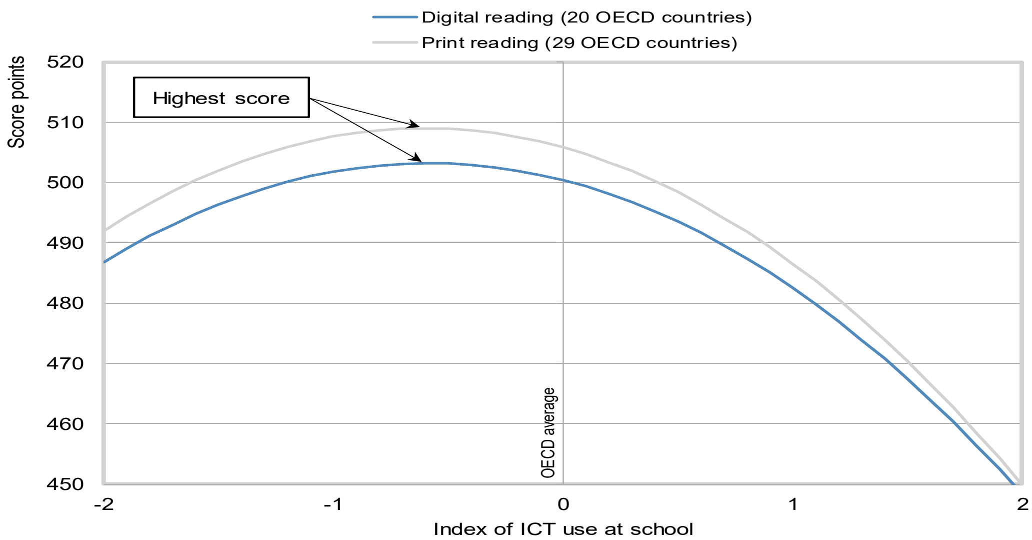
How students use digital devices matters for the benefits they can derive from new technologies. As time spent online increases, so do the opportunities (e.g. for learning) as well as risks (e.g. cyberbullying, excessive use, exposure to inappropriate content) associated with technology use (21st Century Children project, (Hooft Graafland, 2018[15])). In addition, divides in Internet and digital devices use also matter because they often reproduce or even amplify existing inequalities (Van Deursen et al., 2017[16]). Students from socio-economic disadvantaged backgrounds, as well as low-skilled students, are less likely to use digital devices at home for reading news or obtaining practical information from the Internet than their more advantaged peers do (OECD, 2019[2]). Some students may fail to use technology or to use it satisfactorily because they have different levels of motivation or dispositions towards technology than other peers (Helsper, 2017[17]).

The use of digital technologies in schools can help foster the digital competence individuals need to seize the benefits brought about by new technologies. While youth are exposed to new technologies from an ever earlier age, not all young individuals are technological savvy (OECD, 2015[13]; OECD, 2017[18]). Albeit few, evaluations that have focused on the effect of technology use on students' digital skills have generally found positive effects (Malamud and Pop-Eleches, 2011[19]; Malamud et al., 2018[20]; Bulman and Fairlie, 2016[12]). Evidence from PISA 2012 showed that students' performance in digital-based assessment versus paper-based one benefitted little from higher levels of computer use. At the same time, the relationship between computer use and performance in a digital environment varied by type of use and country. In Australia, which also displayed high levels of computer use at school, high frequency browsing was associated with higher skills in digital reading (OECD, 2015[13]). However, previous PISA assessments did not focus on measuring ICT competence as a stand-alone domain, but rather in combination with the assessment of students' performance in other subjects (OECD, 2019[4]). In particular, the PISA (2018) assessment aimed to assess reading literacy in a digital environment (OECD, 2019[14]). In addition, the PISA (2024) assessment of "Learning in the Digital World" will move a step forward in this area and examine the extent to which students can 'use digital tools and resources to learn to model complex systems and solve problems computationally", focusing on the cognitive practices associated with learning with digital tools and on how students regulate their own thinking when learning with such tools (OECD, 2020[21]). Complex tasks will be presented to students in digital environments and students' performance will be based on their ability to use digital tools both to grasp relationships between agents as well as to display their understanding in a computational model (OECD, 2020[21]). Student will thus be led to engage in self-regulatory processes and adapt to feedback they receive from the digital environments.

When it comes to the relationship between ICT use and student performance in academic subjects, analytical results based on PISA data reveal a bell-shaped relationship between students' ICT use and their test scores in reading, mathematics and science. More moderate uses of digital devices at school may be more beneficial rather than no uses, but too high levels of use are associated with lower student scores (Figure 2). Students with very high and very low levels of digital device use at school tend to display poorer performance in reading, science or mathematics (OECD, 2019[2]), and even collaborative problem solving (OECD, 2017[22]). A similar pattern emerges with respect to adolescents' mental well-being (OECD, 2017[23]).

Figure 2. 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



Note: 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.
Source: (OECD, 2015[13]).

Analyses based on PISA data suggest therefore that the way technology is blended into teaching and learning practices is crucial for ensuring that its use can lead to better student outcomes. These results are consistent with those from the wider research evaluation literature that has examined the impact of specific technology-based interventions (e.g. enhanced access to ICT, use of educational software) on students' outcomes, although new forms of technology are constantly emerging (Box 1). Digitalisation has brought new opportunities for personalising learning and research evidence shows that digital solutions or devices based on such features (e.g. educational software that adapts to students' needs) can be effective in raising student outcomes (Roschelle et al., 2016[24]). Personalisation of learning is based on identifying the existing knowledge and difficulties students have, making a diagnosis of the next steps students should take and recommending the pedagogical approach (OECD, 2020[25]). Assessments fuelled by learning analytics can more easily adapt to students' needs and learning patterns, and thereby provide more effective support to students as they go through their tasks while also enhancing their engagement (OECD, 2020[26]). Learners are thus proposed resources and approaches that are in line with their needs and that they can go through at their own pace. Learning personalisation is one of the main contributions of learning analytics and adaptive learning (OECD, 2019[10]).

Evidence thus indicates that when technology is used as an amplifier for teaching or complements teachers in their practices in innovative ways, it can translate into higher student performance and engagement (OECD, 2015[13]; Paniagua and Istance, 2018[27]; OECD, 2019[2]). Pedagogies, or "specific configurations of teaching and learning in interaction", play a substantial role in harnessing the potential of new technologies and digital environments for learning as emphasized by the "Innovative Pedagogies for Powerful Learning" OECD project (Paniagua and Istance, 2018[27]). Introducing new technologies in schools and classrooms requires adjusting and innovating pedagogies to ensure that digital environments and technology use can amplify teaching and translate into improved outcomes (Table 1). For instance, evidence shows that students display higher performance in digital environments when relying on active strategies (e.g. making inferences from information) rather than passive ones (e.g. taking notes), therefore pedagogies should seek to encourage active learning and collaboration when using digital tools (Paniagua and Istance, 2018[27]). Similarly, the use of technology should not be an objective per se and pedagogies need to enhance students' motivation "through" technology rather than simply "to" using technology. Digital environments and technology use, whether in the shape of general ICT, multimedia materials or collaborative environments, hold both strong potential for learning but also disadvantages, and pedagogical practices play a key role in shaping their effects on student outcomes.

Table 1. The role of pedagogies in shaping the use of technology in the classroom

Digital environments and technology use	How pedagogies can be attuned to harness the power of digital environments and technology use for learning			
General ICT (digital technology - e.g. computers, smartphones, and software)	Use ICT as a complement to teaching practices	Enhance motivation "through" and not "to" technology	Promote digital literacy and ensure students have prior competences to use digital tools	Encourage active learning and collaboration
Multimedia materials (combinations of verbal and non-verbal technology-based content - e.g. video clips, e-books, and PowerPoint slides).	Use sound instructional designs	Encourage multimedia authoring as a tool for thinking skills, communication and self-expression development	Accompany students, scaffolding the use of materials	Ensure contents can be understood and learners can stay focused
Multi-tasking and interactive environments (the performance of different tasks at the same time - e.g. watching videos, reading online, and sending messages- in environments that are responsive to users' actions)	Enhance awareness of multi-tasking and of its consequences	Design and implement environments based on sound pedagogical approaches	Address harmful multi-tasking	Promote the use of knowledge frameworks to help students connect new information with prior knowledge
Gaming (the use of video games in school settings)	Ensure the integration of video games into the instructional context	Ensure exploration and manipulation of realistic scenarios	Ensure students focus on the learning elements of games	Provide feedback to students and align games to their learning capacity
Collaborative and Web 2.0 environments (the use of digital tools for collaborative and social activities- e.g. blogs, social networking sites, and wikis)	Ensure Web 2.0 principles are followed (e.g. student-generated content, interaction and collaboration)	Avoid transmission of content by the teacher/ relegation of students to passive roles	Enhance students' capacities to self-regulate and remain focused	Put forward new ways of collaboration and learning based on Web 2.0 tools, extending learning outside the classroom

Source: (OECD, 2019[2]), adapted from (Peterson et al., 2018[28])"Understanding innovative pedagogies: Key themes to analyse new approaches to teaching and learning", https://www.oecd-ilibrary.org/education/understanding-innovative-pedagogies_9f843a6e-en.

Given the mixed results emerging from the research literature (Bulman and Fairlie, 2016[12]; Escueta et al., 2017[29]) (Box 1) and analyses based on several PISA rounds on the relationship between ICT use and student outcomes, the PISA (2021) ICT framework aims to further refine the type of data collected on the modalities of students' and teachers' use of ICT (OECD, 2019[4]). In particular, it will seek to document not only the frequency of digital devices uses, but also the intensity and modalities of ICT use by students, including the use of ICT for non-learning activities (OECD, 2019[4]). PISA 2018 already collects data on the amount of time spent using digital devices in given classes (e.g. mathematics, science) and on whether digital devices have been used in the last month in specific classes, by students or teachers, for learning activities. The PISA 2021 ICT framework makes a step further in this direction, focusing on the amount of time digital devices are used in each class, the recurrence of the use, the ways in which students engage in ICT for learning as well as non-learning activities (OECD, 2019[4]).

Box 1. Digital technologies in school education – some examples and evidence on their effectiveness

The use of technology holds immense promise for learning and skills development, and the introduction and use of computers and Internet in schools has been one of the main drivers of innovation in education practices observed in the past decade in OECD countries (Vincent-Lancrin et al., 2019[30]).

Access to computers and Internet

Enhancing the availability of ICT infrastructure and Internet connectivity has been at the core of almost all digital strategies in education in OECD countries (OECD, 2020[11]). Simply expanding access to ICT resources in schools (e.g. computer hardware or Internet access) is, however, insufficient to enhance student performance. Analyses based on PISA (2012) data show that resources invested in ICT for education (e.g. average number of computers per student) are not linked to improved student achievement in reading, mathematics or science (OECD, 2015[13]). Evidence from the experimental and quasi-experimental evaluation literature supports these findings: increases in ICT investments in the form of computers, laptops or tablets for schoolchildren display little or no positive effects on students' educational outcomes (Bulman and Fairlie, 2016[12]).

Computer-assisted instruction

The use of computer-assisted instruction or educational software or has provided more promising results (than interventions focused on enhancing ICT access at home and at school), especially in mathematics (Bulman and Fairlie, 2016[31]; Escueta et al., 2017[32]; Abdul Latif Jameel Poverty Action Lab, 2019[33]). In contrast to programmes that target general investments in computers or Internet connectivity to expand access, computer-assisted instruction focuses on "well-defined uses of specific software packages (Escueta et al., 2017[29])".

The design of the PISA ICT questionnaire has not allowed capturing the specific use of computer-assisted instruction in school-based settings. Evidence on the effectiveness of educational software mostly stems therefore from the research literature. Unlike general investments in ICT resources, educational software grants more opportunities for personalising instruction that allows targeting students' specific needs and informing teachers about students outcomes, thereby allowing them to adapt their own instruction practices (Abdul Latif Jameel Poverty Action Lab, 2019[33]).

Online laboratories

Online laboratories (remote or virtual) have provided novel learning and teaching opportunities in the area of STEM (Kärkkäinen and Vincent-Lancrin, 2013[34]). Virtual online laboratories give the possibility to perform simulations of scientific experiments. Remote laboratories provide students with access to laboratory equipment situated elsewhere through an Internet connection. Both types of online laboratories offer benefits in terms of limiting the costs of access to experimental learning, enhanced flexibility (e.g. in terms of study time) and student learning. Indeed, such laboratories can either act as a complement or even substitute for school labs, provided that students and teachers have access to the Internet. Research has brought evidence that the use of such laboratories has been associated with positive outcomes in terms of students' understanding of science and achievement.

Technology-enabled collaboration

Technology provides new means for enhanced collaborative learning, whether across long distances or between students of different cultures (Kärkkäinen and Vincent-Lancrin, 2013[34]). Technology-enabled collaboration displays a large number of potential benefits, in terms of enhanced flexibility (e.g. student scan collaborate at any time, from anywhere), cultural diversity (e.g. by increasing the scope of collaborations across borders), student learning (though not necessarily more than in-person interactions), student interaction and engagement, as well as thinking skills. Evidence from three projects unfolded in China, Russia and the United Kingdom show that technology-enabled collaboration can enhance students' trust as well as their performance.

Emerging technologies: Artificial Intelligence

Although still emerging and used in local or experimental contexts (Vincent-Lancrin and van der Vlies, 2020[35]), the rise of Artificial Intelligence (AI) has brought new opportunities for personalising learning and learning materials, and thereby further enhancing the effectiveness of computer-assisted instruction. The AI Group of Experts at the OECD defined an AI system as "a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations or decisions influencing real or virtual environments. It uses machine and/or human-based inputs to perceive real and/or virtual environments; abstract such perceptions into models; and use model inference to formulate options for information or action. AI systems are designed to operate with varying levels of autonomy" (OECD, 2019[36]).

AI brings immense promise for the personalisation of instruction: AI Applications allow identifying materials and approaches in line with each student's needs and, relying on data from students, make predictions and recommendations about how to pursue learning activities (Vincent-Lancrin and van der Vlies, 2020[35]). One example of AI application used for personalising instruction is the "Teach for One" math programme implemented in eight lower-secondary schools from Chicago, New York City and Washington DC. The programme relies on daily assessments of students' skills in order to target how content is subsequently delivered and provide different types of instruction methods to students (e.g. teacher-led instruction, virtual adaptive tutoring). Learning paths are reconfigured daily based on collected data. Teachers also receive real-time information about student performance.

Another application of AI for instruction involves the provision of support for students with disabilities. Devices relying on AI can help students with visual impairments read books or recognise faces. Similarly, augmented and virtual reality fuelled by AI can support students with health impairments or mental issues.

Other AI applications revolve round the provision of online and blended learning (e.g. chatbots that provide students with analytics on their learning), classroom dynamics (e.g. sensors to analyse student engagement to offer teachers real time feedback and recommendations) and foreign language learning.

Source: (Vincent-Lancrin and van der Vlies, 2020[35])

Digital technologies as tools to support teachers

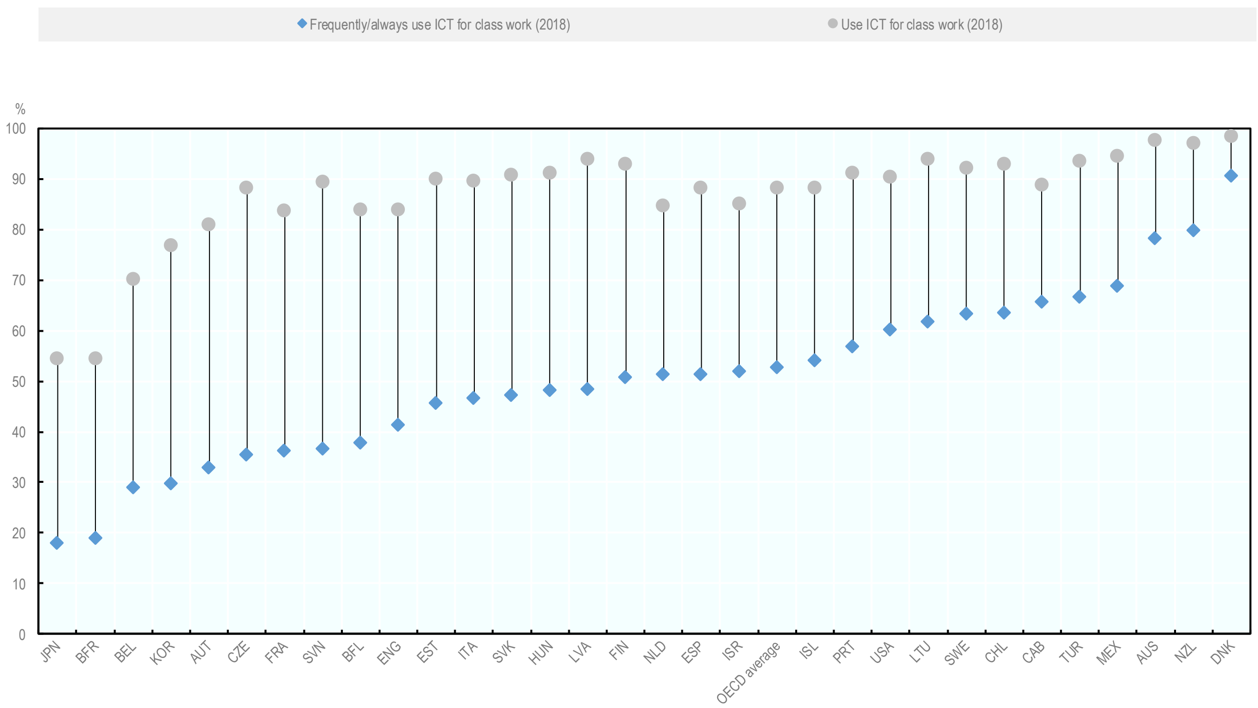
Teachers' use of technologies in the classroom

Teachers are at the core of the integration of new technologies into innovative teaching and learning practices that can translate into enhanced student performance. Across OECD countries with available data in TALIS (2018), the use of ICT for class work is not widespread, although it has been on a rise (OECD, 2019[37]). On average, 53% of lower-secondary teachers in OECD countries report that they frequently or always let their students use ICT for projects or class work (Figure 3). These figures hide large cross-country variations. While almost all teachers in Denmark use ICT as part of their teaching practices and 90% of them do so with high frequency, fewer than 20% of teachers in Japan report using ICT for class work frequently or always.

While TALIS data provide information on teachers' reliance on ICT as part of their teaching practices, they do not detail the specific uses that teachers and students make of these technologies, nor the amount of time devoted to them or their association with more innovative teaching practices. Data from the PISA (2018) ICT familiarity questionnaire enable distinguishing whether digital devices are used for learning or teaching during lessons, by subject and by the user of the digital device (teachers, students or both). Indicators are also available on the amount of time students use digital devices during classroom, in different subjects. However, the specific modalities of ICT use, whether by teacher or students, are not explored and the PISA 2021 ICT questionnaire is meant to provide a more comprehensive perspective on students and teachers' use of ICT (OECD, 2019[4]).

Figure 3. Teaching practices- using ICT for class work

Percentage of teachers who reported that they use the following practices in their class: let students use ICT for projects or class work



Source: OECD calculations based on TALIS (2018).

Teachers' reliance on ICT as part of their teaching practices can be enabled by many factors, from the mere availability of high-quality ICT infrastructure in their school, to teachers' digital competencies and attitudes, school regulations or wider contextual factors. Analyses based on TALIS (2018) show that training in ICT skills for teaching, teacher self-efficacy and collaboration with other teachers matter for teachers' frequent use of ICT in class and self-efficacy in supporting student learning using digital technologies (OECD, 2020[8]). In addition, teachers' attitudes towards ICT are also instrumental in teachers' reliance on ICT as part of their practices. Teachers with more constructivist beliefs or who are more positive about the usefulness of new technologies are more likely to use digital technologies more frequently (European Commission, 2013[38]; Gil-Flores, Rodríguez-Santero and Torres-Gordillo, 2017[39]). On the contrary, teachers' age and experience do not appear to contribute to the frequency with which teachers' let their students use ICT for project or class work, when teacher ICT training, collaboration among teachers, perceived self-efficacy in instruction and constructivist beliefs are accounted for (Gil-Flores, Rodríguez-Santero and Torres-Gordillo, 2017[39]; OECD, 2020[8]).

School regulations, curricular requirements, incentives to reward the use of ICT in creative ways or wider innovation strategies in education systems can equally play a role in supporting teachers' reliance on ICT as part of their teaching practice. However, data related to teachers' use of ICT has covered the presence of such policy incentives or regulations only in a limited way. Analyses based on PISA (2012) (OECD, 2015[13]) and TALIS (2018) (OECD, 2020[8]) show that most of the variation in the frequency of ICT use as part of learning and teaching practices lies within schools, as opposed to between schools. Teacher and student-level factors are likely to matter more for the extent to which ICTs are used within the classroom. School-level policies may indeed put a stronger focus how ICTs are used rather than on the frequency of their use (OECD, 2015[13]).

More detailed data in PISA and/or TALIS on the modalities of ICT use for learning and teaching, the presence of school policies or regulations related to ICT use as well as indicators available at a more aggregate level focusing on policies or incentives related to the use of ICTs would enable refining these analyses. PISA (2018) provides some additional information on the presence of school guidelines and practices to enhance teaching and learning using digital devices (Annexe B).

New technologies can also support teachers in classroom assessment, for formative or other types of assessments at the individual level. Indeed, the "Smart Data and Digital Technology in Education: Learning Analytics, AI and beyond" project emphasizes how Artificial Intelligence provides new directions in terms of skills assessment, triggering a shift away from standardised assessments that are at the core of many education systems. Novel assessments fuelled by AI or similar technologies could rely on how students react in different learning situations, behave or think. Game-based assessment using digital technologies and simulations are other examples of relying on new technologies (e.g. augmented reality, AI) that allow adapting to each students' skills while equally providing novel ways of assessing complex skills (Vincent-Lancrin and van der Vlies, 2020[35]; OECD, 2019[10]). Moreover, classrooms can be designed as hybrid digital-physical spaces, with sensors and computers analysing learner behaviour and providing feedback to teachers on student learning as well as on ways of enhancing teaching practices (OECD, 2019[10]). In addition, online learning environments, together with the development of novels methods of data collection and advances in learning analytics, can also transform the way assessment is carried out. A new project initiative in the context of PISA focuses on the development of an innovative assessment platform that integrates learning analytics (OECD, 2020[26]). Data from students' interactions with digital tools can provide information both on their disciplinary knowledge, as well as on their thinking and learning skills, offering new opportunities to support teachers in engaging students and monitoring their learning processes and outcomes.

Teachers' use of technologies for activities outside the classroom

Teachers' use of ICT extends outside of the classroom and specific teaching practices, and new technologies can support teachers in more effectively using their time, thereby relieving pressure and potentially reducing stress. Data from TALIS (2018) show that, in OECD countries, individual planning or preparation of lessons, marking of student work, general administrative work and team work with colleagues within the school are teachers' most time-consuming non-teaching activities. At the same time, teachers devoting many hours to administrative work or grading are more likely to report higher levels of stress in contrast to teachers who devote more hours to actual teaching (OECD, 2020[40]).

The OECD Survey of Adult Skills (PIAAC) provides information on adults', including teachers', ICT intensity at work, an indicator based on tasks associated with ICT use at work (e.g. reading and writing emails, using word-processing or spreadsheet software, programming). On average in OECD countries with available data, teachers use ICT at work with almost similar intensity as other tertiary-educated workers (OECD, 2019[2]). In Greece, Italy and Turkey, teachers' use of ICT is low and it is equally below the use of

ICTs by high-skilled workers. Data from the OECD Survey of Adult Skills (PIAAC) do not cover teachers' specific ICT uses at school or outside of school for school-related activities.

The PISA 2021 ICT framework puts more focus on documenting more in detail teachers' reliance on technologies outside the classroom. In particular, it puts an emphasis on the extent to which ICT can support teachers' activities outside of the classroom: communication and information sharing, professional collaboration and knowledge sharing, professional development and harnessing educational data for better teaching (OECD, 2019[4]).

Data from the European Commission provides additional insights. Teachers increasingly rely on new technologies for communicating with parents and students, preparing lessons, testing new practices before introducing them into the classroom or more generally as part of their daily activity in the school. Around 60% of European students across all ISCED levels (ISCED 1 to 3) were in schools where teachers used ICT to communicate with parents and more than 90% in schools where teachers reported using ICT to prepare lessons (European Commission, 2019[41]).

In addition, digitalisation also expands the ways in which teachers learn and collaborate. New forms of delivery of teacher professional learning, as well as teacher collaboration, have been enabled by digital environments. Innovative forms of professional development, unfolded online or in blended forms, and providing flexible solutions for teachers to participate have emerged (Vuorikari, 2018[42]). Evidence from MOOCs shows that teachers are over-represented in such forms of learning (Seaton, Coleman and Daries, 2014[43]). In addition, online communities offer new possibilities for knowledge co-creation and sharing resources. Such communities have provided teachers with new spaces to filter ideas and information, as well as engage in supportive professional practices (Lantz-Andersson, Lundin and Selwyn, 2018[44]).

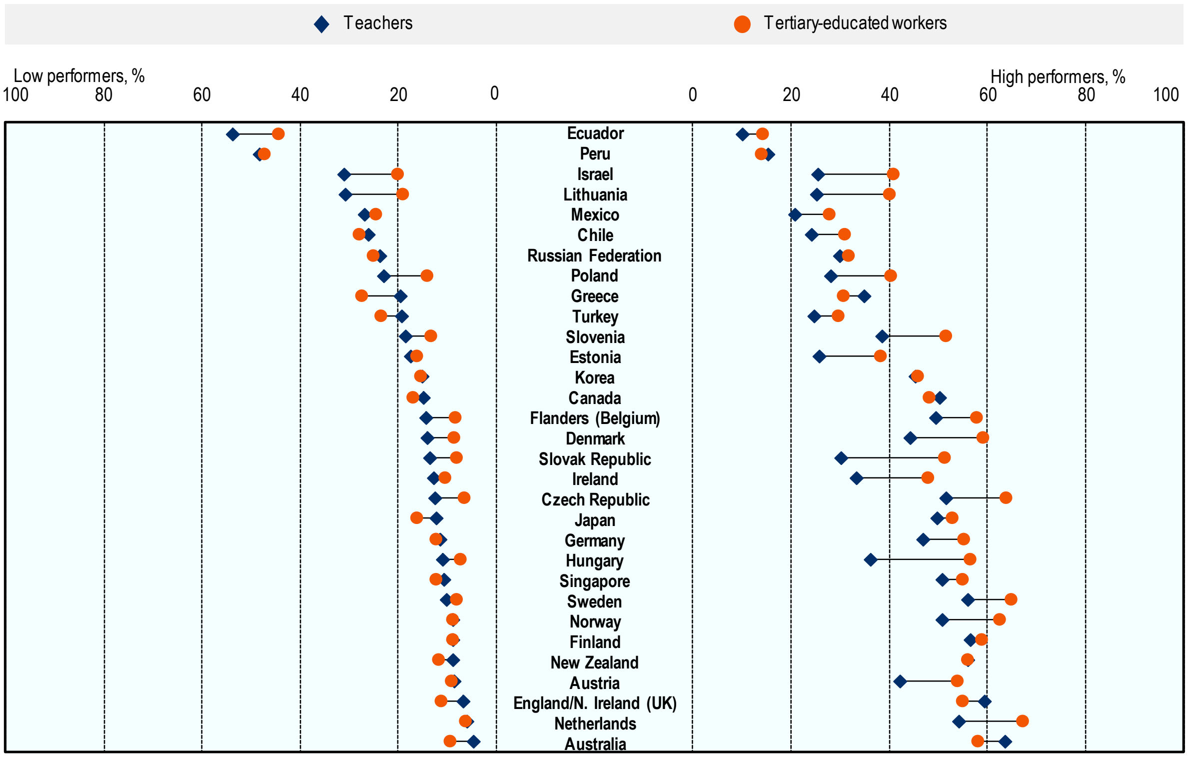
Developing teachers' digital competence

The teaching profession is at the core of the integration of new technologies in school education and teachers' digital competence plays an instrumental role in seizing the benefits of new technologies for learning (OECD, 2019[2]). The quality of learning and student achievement is closely related to the quality of teaching and differences in the cognitive skills of teachers can help explain international differences in student performance in OECD countries (Hanushek, Piopiunik and Wiederhold, 2014[45]). A similar positive association is observed between students' performance in computer mathematics and problem solving, and teachers' problem solving skills in technology-rich environments (OECD, 2019[2]).

The OECD Survey of Adult Skills (PIAAC) defines problem solving in technology-rich environments as "using digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks" (OECD, 2012[46]). Teachers appear to be as likely as tertiary-educated workers to be low performers in problem solving in technology-rich environments, but less likely to be high performers (Figure 3). Many OECD countries would experience sizeable increases in students' computer-based achievement, were their teachers' problem-solving skills in technology-rich environments be similar to those of Australian teachers, the highest-performing ones in the sample.

Figure 4. Teachers' problem solving in technology-rich environment proficiency

Share of poor and top performing teachers and tertiary-educated workers in problem solving in technology-rich environments, by country (%)



Source: OECD (2020) based on the Survey of Adults Skills (PIAAC) (2012, 2015, 2017) (database), http://www.oecd.org/skills/piaac/.

While the OECD Survey of Adult Skills does not cover teachers' ICT skills for teaching, TALIS data provide information on the preparation and support provided to teachers to enable them to use ICT as part of their teaching activities. Only 56% of lower-secondary teachers from OECD countries benefitted from training in the use of ICT for teaching as part of their initial teacher education and 43% of them felt well or very well prepared to use ICT in teaching after their initial education and training (OECD, 2019[37]). In addition, around 60% of lower-secondary teachers from OECD countries with available data in TALIS (2018) report professional development needs to enhance their ICT skills for teaching and around 20% report a high level of need (OECD, 2020[8]). The Teacher Knowledge Survey assessment module for TALIS 2024 will further examine these issues (in terms of teachers' knowledge and initial teacher education/ continuous professional development).

Both participation in and the quality of ICT-related training activities matter for enabling teachers' reliance on ICT and ICT-related self-efficacy (OECD, 2020[8]). Merely having benefitted from training in ICT use for teaching as part of teachers' initial education is insufficient to enhance teachers' use of ICT for teaching and self-efficacy if teachers report feeling unprepared for teaching with digital tools. The quality of received training as part of teachers' initial education seems to play a strong role. As for continuous professional development, teachers who participated in professional development activities in ICT skills for teaching in the preceding year were more likely to make use ICT more frequently as part of their teaching activities and to be more confident in their capacity to support student learning using new technologies.

The content of professional learning opportunities plays a strong role in developing teachers' competence in using ICT for teaching (Xiong, 2020[5]). A well-structured and comprehensive training curriculum (combining pedagogical approaches, subject matter and ICT knowledge), practice-based pedagogical methods and peer learning appear to be positively related to teachers' ICT-related learning (Xiong, 2020[5]). The 21st century Children Policy Questionnaire brings some evidence on the type of topics covered by teacher initial education and professional development in the area of ICT use for teaching, although the specific design of ICT-related training opportunities is not covered. Most of the 26 countries responding to the questionnaire provided some form of support to teachers in developing digital skills and integrating technology in teaching activities (Burns and Gottschalk, 2019[3]). In most countries, these topics were required (by national curriculum, standards or other). Measures designed by surveyed OECD countries to provide teacher support have mostly revolved around curriculum reforms and extension, formal teacher education and training, and network approaches to education and training. Most countries reported actions as part of teachers' continuous professional development (e.g. support embedded within schools – *Digital Technologies* programme in Australia, MOOCs –Webwise in Ireland, portals with learning resources for teachers – *Digital Technologies Hub* in Australia) rather teacher initial education (e.g. Digital Laboratoriums in Norway) (Burns and Gottschalk, 2019[3]).

In addition, technology-based training in practicum and as part of continuous professional development activities also matters, as well as benefitting from mentorship support, both from well-trained teacher educators and from school-based cooperating teachers. The likelihood that teachers frequently use ICT as part of their teaching practice and feel confident about supporting student learning using new technologies increases with teachers' degree of collaboration with other teachers (OECD, 2020[8]).

Digital technologies as tools to support the management of schools and education systems

Data and technologies for the management of educational systems

Digitalisation has also brought new opportunities for innovation in education that go beyond the level of the classroom and have the potential to transform the management of educational institutions and systems. The "Smart Data and Digital Technology in Education: Learning Analytics, AI and beyond" project shows that new technologies (e.g. Artificial Intelligence) can bring significant changes to various areas of education systems, among which assessment, learning analytics for parents, schools or school systems, dropout reduction or credentials (OECD, 2019[10]). At the same time, reliance on such technologies in education systems also requires addressing underlying issues related to their trustworthiness, as well as more general data protection and security implications (Vincent-Lancrin and van der Vlies, 2020[35]). The preparedness of teachers, school principals and school leaders to make use of such novel technologies is equally crucial to ensure that they are used effectively to achieve the desired outcomes. Data from TALIS (2018) showed that 24% of lower-secondary school principals, on average across OECD countries, reported a high level of need for professional development in using data for improving the quality of the school.

AI solutions can provide support to school principals and district leaders to prevent dropout (Vincent-Lancrin and van der Vlies, 2020[35]). Making novel uses of longitudinal data already available, AI can help predict and prevent dropout, already from an early stage, for instance by more easily visualising students that are at risk of dropping out and suggesting potential interventions. The identification of risks is not equivalent to actually addressing it through effective solutions and research is still ongoing in order to refine both the prediction of dropout as well as the provision of adequate interventions to adequately deal with the risk (Vincent-Lancrin and van der Vlies, 2020[35]; OECD, 2019[10]).

In addition, as data creation and collection expands with the digital transformation, OECD countries are increasingly putting data at the core of their digital strategies. In education systems, data – and big data – can support teachers, school leaders and policy makers in enhancing the effectiveness of their practices and policies. The rise of Artificial Intelligence and the Internet of Things[2], as well as of other emerging technologies, brings new opportunities for the collection and analysis of large amounts of data. (OECD, 2020[11]). Across the OECD, some countries have already taken steps to encourage and support more effective uses of data in order to improve education systems. In New South Wales (Australia), the Centre for Education Statistics and Evaluation is collecting and analysing education data as well as building capacity in the sector to ensure that all actors can more effectively use data and evidence. The centre is also working on enhancing the accessibility of data. In Japan, advanced technology and educational big data is expected to be used to support reforms for teachers and management, focusing on issues related to time management, attendance and results processing (OECD, 2020[11]).

Learning analytics is another area with great potential for supporting the management of education systems. Learning analytics relying on administrative data can provide quicker support to schools or monitoring virtually immediately the effectiveness of policy interventions. It can also support early warning systems. In addition, learning analytics can also be used to support parents in respect to their children's schooling (e.g. absences, grades, and homework) as well as non-formal learning, with great potential for reducing truancy, dropout as well as enhancing student learning (OECD, 2019[10]).

Digital strategies for education systems

To make the most of digital transformation, OECD countries have put in place national digital strategies. However, few of these digital strategies display the required level of government engagement, range of policy coverage and concreteness of policy response to ensure an efficient and coordinated policy effort in response to the digital transformation (OECD, 2019[2]). An OECD policy survey on the topic identified the promotion of ICT-related skills and competences as one of the top three policy objectives of OECD countries for the development of the digital economy and society. All 38 countries that replied to the skills section of the survey had at least one type of ICT education and training policy in place (OECD, 2017[47]).

Around 75% of countries reported to allocate funds to set ICT literacy objectives in state/federal curricula and more than 70% to buy ICT goods and services for students. The most frequent types of public expenditures on ICT goods and services in education were related to financial support for ICT equipment or Internet connections for public schools: around 50% of surveyed countries reported implementing each of these policy types. Policies for buying or developing digital learning materials (e.g. e-textbooks) were less common (reported by 25% of surveyed countries) (OECD, 2017[47]).

In the context of the "Smart Data and Digital Technology in Education: Learning Analytics, AI and beyond" project, a more recent mapping of OECD countries' and partners' digital policies in education shows that in most OECD countries, digital policies in education revolve around ICT infrastructure and digital learning environments, as well as addressing challenges related to fostering digital competence and bridging digital divides (OECD, 2019[10]; OECD, 2020[11]). Enhancing access to high-speed Internet connection and digital devices (e.g. computers) is at the core of many national digital education strategies in OECD countries (OECD, 2020[11]). Digital strategies related to learning environments focus either on the provision of easier access to quality learning resources or platforms (e.g. MOOCs, digital educational resources) to students and teachers, or on the facilitation of digital learning environments in schools and classrooms (e.g. through learning management and information systems). The policy focus in the area of digital competence typically focuses around the need to develop new types of skills, and the provision of support and professional development to school teachers as they are required to teach these new skills. Information on the funding of these different types of digital education policies is however often lacking from most of the reviewed policy strategies (OECD, 2019[10]).

Given the scarce evidence on the policy environment related to ICTs in school education in data collections at the OECD, the PISA 2021 ICT framework emphasizes the need to document the national policies, regulations and guidelines that shape the availability and use of ICTs in education systems (OECD, 2019[4]). Collected information in PISA 2021 on the policy environment could cover both i) the regulatory framework regarding the quantity and quality of ICT resources in schools and ii) policies and guidelines framing the use of ICT resources by students and teachers in school.

Areas for further policy analyses

As shown above, previous OECD data collections have primarily focused on the availability of and reliance on ICTs at the school or classroom level, and only recently shifted towards gathering more information on school policies or guidelines related to ICT use (Annexe B). Regarding levels of education, there is a lot of data collected at the level of secondary schools, but much less so for early childhood education and care (ECEC), primary and upper secondary education.

OECD analyses have mostly revolved around the use of ICT in school education and in particular, as part of teaching and learning activities. Fewer strands of work have addressed questions related to digital policies for education systems. Many gaps remain from a policy perspective related to ICTs as a resource in education systems. In particular, there are many questions related to the governance, distribution and management of ICT resources, which could addressed from an international perspective, building on the framework of the OECD School Resources Review. These are outlined in the following sub-sections.

Governance and funding of ICT resources:

- Who chooses ICT resources and how to use them?
- Are there norms and regulations that guide the use of ICT (at different levels of the system)?
- How much leeway do schools and teachers have to choose digital tools, organise the use of ICT for learning and other activities?
- What funding is available for ICT in school education and what are the funding sources?
- What are the trade-offs when investing in different types of ICT over other types of resources?
- How to ensure that costs associated with ICT resources are contained while technological innovations constantly require investments in the renewal, update or maintenance of hardware, software and/or users' competencies?
- What tools can governments rely on to decide among different types of technology, especially when technology is changing so fast?
- What are successful models of public-private partnerships?
- Where and for which students do ICT investments seem most beneficial?
- How can ICTs bring about innovation in working practices and enhance efficiency?

Distribution of ICT resources:

- How are ICT resources distributed between different education levels, across different groups of students (e.g. with special needs, from low socio-economic background, low-performers) or types of schools (e.g. schools in remote areas)?
- Are ICT resources targeted directly at students or channelled through schools (or specific types of schools)?
- Are ICT resources matched to students' needs (e.g. adaptive educational software) and how does this relate to students' levels/ heterogeneity in students' needs?

- How are ICTs integrated into students' learning time? What are optimal levels of ICT use relative to traditional instruction?
- Are ICT-based programmes intended to increase instruction time at school or at home, or to substitute other activities?

Management and evaluation of ICT resources:

- Are there incentives for the effective use of ICT at different levels of the system?
- Are schools (e.g. norms, regulations) and school leaders (e.g. attitudes) conducive to the use of ICT in innovative ways?
- Do teachers benefit from support / feedback / rewards on innovative approaches using ICT?
- Are school leaders and education system leaders prepared to manage ICT resources, monitor their use and ensure its effectiveness?
- How to ensure safety and security of data and privacy in education systems that increasingly rely on new technologies?
- Are ICT-based programmes evaluated and how is the collected evidence used?
- What role for piloting, experimentation and product-testing before scaling up ICT-based programmes?
- What is known about effective programme design and which components of ICT-related programmes are more efficient? (e.g. are positive effects driven by the ICT part of programmes or by other components of these programmes such as additional instruction time, teacher support, or better-trained teachers)?

Notes

[1] Learning analytics focuses on "how to employ data mining, machine learning, natural language processing, visualization, and human-computer interaction approaches among others to provide educators and learners with insights that might improve learning processes and teaching practice" (OECD, 2019[10]).

[2] The Internet of Things comprises "all devices and objects whose state can be altered via the Internet, with or without the active involvement of individuals" (OECD, 2019[10]).

References

Abdul Latif Jameel Poverty Action Lab (2019), "Will technology transform education for the better?", *J-PAL Evidence Review*, Cambridge, MA, https://www.povertyactionlab.org/sites/default/files/documents/education-technology-evidence-review.pdf. [33]

Bell, T. (2016), *What's all the fuss about coding?*, Australian Council for Educational Research, https://research.acer.edu.au/cgi/viewcontent.cgi?article=1288&context=research_conference (accessed on 27 March 2018). [51]

Bulman, G. and R. Fairlie (2016), "Technology and education: Computers, software, and the Internet", in *Handbook of the Economics of Education*, http://dx.doi.org/10.1016/B978-0-444-63459-7.00005-1. [49]

Bulman, G. and R. Fairlie (2016), "Technology and Education: Computers, Software, and the Internet", in *Handbook of the Economics of Education*, http://dx.doi.org/10.1016/B978-0-444-63459-7.00005-1. [12]

Bulman, G. and R. Fairlie (2016), "Technology and Education: Computers, Software, and the Internet", in *Handbook of the Economics of Education*, http://dx.doi.org/10.1016/B978-0-444-63459-7.00005-1. [31]

Burns, T. and F. Gottschalk (eds.) (2019), *Educating 21st Century Children: Emotional Well-being in the Digital Age*, Educational Research and Innovation, OECD Publishing, Paris, https://dx.doi.org/10.1787/b7f33425-en. [3]

Escueta, M. et al. (2017), "Education technology: An evidence-based review", *NBER Working Paper*, No. 23744, http://www.nber.org/papers/w23744. [32]

Escueta, M. et al. (2017), "Education Technology: An Evidence-Based Review", http://www.nber.org/papers/w23744. [29]

European Commission (2019), *2nd Survey of Schools: ICT in Education - Objective 1: Benchmark progress in ICT in schools*, Luxembourg: Publications Office of the European Union, http://dx.doi.org/10.2759/23401. [41]

European Commission (2013), *Survey of Schools: ICT in Education*, Luxembourg: Publications Office of the European Union, http://dx.doi.org/10.2759/94499. [38]

Gil-Flores, J., J. Rodríguez-Santero and J. Torres-Gordillo (2017), “Factors that explain the use of ICT in secondary-education classrooms: The role of teacher characteristics and school infrastructure”, *Computers in Human Behavior*, Vol. 68, pp. 441-449, http://dx.doi.org/10.1016/j.chb.2016.11.057. [39]

Hanushek, E., M. Piopiunik and S. Wiederhold (2014), “The value of smarter teachers: International evidence on teacher cognitive skills and student”, *NBER Working Paper Series*, No. 20727, http://www.nber.org/papers/w20727 (accessed on 13 April 2018). [45]

Helsper, E. (2017), “A socio-digital ecology approach to understanding digital inequalities among young people”, *Journal of Children and Media*, Vol. 11/2, pp. 256-260, http://dx.doi.org/10.1080/17482798.2017.1306370. [17]

Hooft Graafland, J. (2018), “New technologies and 21st century children: Recent trends and outcomes”, *OECD Education Working Papers*, No. 179, OECD Publishing, Paris, https://dx.doi.org/10.1787/e071a505-en. [15]

Kärkkäinen, K. and S. Vincent-Lancrin (2013), “Sparking Innovation in STEM Education with Technology and Collaboration: A Case Study of the HP Catalyst Initiative”, *OECD Education Working Papers*, No. 91, OECD Publishing, Paris, https://dx.doi.org/10.1787/5k480sj9k442-en. [34]

Lantz-Andersson, A., M. Lundin and N. Selwyn (2018), “Twenty years of online teacher communities: A systematic review offormally-organized and informally-developed professional learning groups”, *Teaching and Teacher Education*, Vol. 75, pp. 302-315. [44]

Leuven, E. et al. (2007), “The effect of extra funding for disadvantaged pupils on achievement”, *The Review of Economics and Statistics*, Vol. 89/4, pp. 721–736, https://www.mitpressjournals.org/doi/pdf/10.1162/rest.89.4.721. [50]

Lorenceau, A., C. Marec and T. Mostafa (2019), *Upgrading the ICT questionnaire items in PISA 2021*, OECD Working Paper Series, http://www.oecd.org/edu/workingpapers (accessed on 8 April 2020). [7]

Malamud, O. et al. (2018), *Do Children Benefit from Internet Access? Experimental Evidence from Peru*, National Bureau of Economic Research, Cambridge, MA, http://dx.doi.org/10.3386/w25312. [20]

Malamud, O. and C. Pop-Eleches (2011), “Home computer use and the development of human capital”, *The Quarterly Journal of Economics*, Vol. 126/2, pp. 987-1027, http://dx.doi.org/10.1093/qje/qjr008. [19]

OECD (2020), *Coronavirus and the future of learning: What AI could have made possible - OECD Education and Skills Today*, https://oecdedutoday.com/coronavirus-future-learning-artificial-intelligence-ai/ (accessed on 28 May 2020). [25]

OECD (2020), *Digital strategies in education - Exploring education policies on digital technologies*. [11]

OECD (2020), *Latin American Economic Outlook 2020*, OECD Publishing, Paris. [52]

OECD (2020), *Making the Most of Technology for Learning and Training in Latin America*, OECD Skills Studies, OECD Publishing, Paris. [8]

OECD (2020), *PISA 2024 LEARNING IN THE DIGITAL WORLD ASSESSMENT DESCRIPTION*. [21]

OECD (2020), *TALIS 2018 Results (Volume II): Teachers and School Leaders as Valued Professionals*, TALIS, OECD Publishing, Paris, https://dx.doi.org/10.1787/19cf08df-en. [40]

OECD (2020), *The Platform for Innovative Learning Assessements (PILA): a new resource for assessing learning skills*. [26]

OECD (2019), *Artificial Intelligence in Society*, OECD Publishing, Paris, https://dx.doi.org/10.1787/eedfee77-en. [36]

OECD (2019), *OECD Skills Outlook 2019 : Thriving in a Digital World*, OECD Publishing, Paris, https://dx.doi.org/10.1787/df80bc12-en. [2]

OECD (2019), *PISA 2018 Results (Volume I): What Students Know and Can Do*, PISA, OECD Publishing, Paris, https://dx.doi.org/10.1787/5f07c754-en. [14]

OECD (2019), *PISA 2021 ICT Framework*, OECD Publishing, Paris. [4]

OECD (2019), *Smart Data and Digital Technology in Education: Learning Analytics, AI and beyond*. [10]

OECD (2019), *TALIS 2018 Results (Volume I): Teachers and School Leaders as Lifelong Learners*, TALIS, OECD Publishing, Paris, https://dx.doi.org/10.1787/1d0bc92a-en. [37]

OECD (2017), “Innovative Pedagogies for Powerful Learning”, https://one.oecd.org/document/EDU/CERI/CD/RD(2017)10/en/pdf. [18]

OECD (2017), *OECD Digital Economy Outlook 2017*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264276284-en. [47]

OECD (2017), *PISA 2015 Results (Volume III): Students’ Well-Being*, PISA, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264273856-en. [23]

OECD (2017), *PISA 2015 Results (Volume V): Collaborative Problem Solving*, OECD Publishing, http://dx.doi.org/10.1787/9789264285521-en (accessed on 19 December 2017). [22]

OECD (2015), *Students, Computers and Learning: Making the Connection*, PISA, OECD Publishing, http://dx.doi.org/10.1787/9789264239555-en. [13]

OECD (2014), *TALIS 2013 Results: An International Perspective on Teaching and Learning*, TALIS, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264196261-en. [48]

OECD (2012), *Literacy, Numeracy and Problem Solving in Technology-Rich Environments: Framework for the OECD Survey of Adult Skills*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264128859-en. [46]

Paniagua, A. and D. Istance (2018), *Teachers as Designers of Learning Environments: The Importance of Innovative Pedagogies*, Educational Research and Innovation, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264085374-en. [27]

Peterson, A. et al. (2018), “Understanding innovative pedagogies: Key themes to analyse new approaches to teaching and learning”, *OECD Education Working Papers*, No. 172, OECD Publishing, Paris, https://dx.doi.org/10.1787/9f843a6e-en. [28]

Reimers, F. and A. Schleicher (2020), *A framework to guide an education response to the COVID-19 Pandemic of 2020*. [6]

Roschelle, J. et al. (2016), “Online Mathematics Homework Increases Student Achievement”, *AERA Open*, Vol. 2/4, p. 233285841667396, http://dx.doi.org/10.1177/2332858416673968. [24]

Seaton, D., C. Coleman and J. Daries (2014), “Teacher Enrollment in MIT MOOCs: Are We Educating Educators?”, *SSRN Electronic Journal*, http://dx.doi.org/10.2139/ssrn.2515385. [43]

UNESCO (2020), *School closures caused by Coronavirus (Covid-19)*, https://en.unesco.org/covid19/educationresponse (accessed on 22 April 2020). [1]

Van Deursen, A. et al. (2017), “The Compoundness and Sequentiality of Digital Inequality”, *International Journal of Communication* 11, pp. 452–473, https://ijoc.org/index.php/ijoc/article/view/5739/1911 (accessed on 19 October 2018). [16]

van Deursen, A. and J. van Dijk (2014), “The digital divide shifts to differences in usage”, *New Media & Society*, Vol. 16/3, pp. 507-526, http://dx.doi.org/10.1177/1461444813487959. [9]

Vincent-Lancrin, S. et al. (2019), *Measuring Innovation in Education 2019: What Has Changed in the Classroom?*, Educational Research and Innovation, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264311671-en. [30]

Vincent-Lancrin, S. and R. van der Vlies (2020), “Trustworthy artificial intelligence (AI) in education: Promises and challenges”*, OECD Education Working Papers*, No. 218, OECD Publishing, Paris, https://dx.doi.org/10.1787/a6c90fa9-en. [35]

Vuorikari, R. (2018), “Innovating Professional Development in Compulsory Education Examples and cases of emerging practices for teacher professional development”, *JRC Technical Reports*, http://dx.doi.org/10.2760/734136. [42]

Xiong, Z. (2020), *Literature review of technology pedagogical and content knowledge (TPACK) (working document)*. [5]

Annexe A. Recent or ongoing OECD projects on digital technologies in school education

- The **"Smart Data and Technology in Education"** project aims to highlight some of the most frontier uses of digital technologies and data in for educational improvement and allow countries to review their digital policies and strategic thinking about their education systems in light of these developments. It focuses on schools, higher education and to a lesser extent lifelong learning. The projects' methodology relies on a mix of analytical work on digital technologies and data use, stakeholder dialogue with policy makers, practitioners, learners, researchers and developers about the futures of education, and policy questions on some key aspects of education data use and access, and on countries' overall administrative data infrastructure. Some of the policy issues will be selected by countries for further investigation towards the end of the first, exploratory phase of the project.
- The **"21st century children"** project examines the nature of modern childhood, with a focus on digital technologies, physical health, emotional well-being and families and peers (and the interactions between them). For the 21-22 biennium, its work on digital technologies will focus on a) digital technologies and the link to student learning outcomes, digital resilience and well-being, b) the ethics of digital engagement, and c) building system capacity (addressing policy fragmentation, supporting teachers in building digital skills, developing partnerships between schools and multiple external actors (for example, mental and physical health professionals, cyber security experts). This project takes a lifespan approach, looking at childhood (ages 0-18) as a whole. It builds on a mix of research reviews/synthesis, policy questionnaire, collaboration with multidisciplinary experts; expert meetings; and international conferences.
- The PISA 2018 Volume V **"Effective Policies, Successful Schools**" will analyse issues related to school organisation – that is, the policies and practices that define how education systems work and change over time. Key aspects of school organisation include the amount and kind of resources available for schools and how these resources are allocated and used. As part of material resources, the Volume will include a special focus on digital devices and IT equipment in schools (e.g. desktop computers, portable laptops, tablet computers, connection to the Internet, interactive whiteboards and data projectors). It will equally explore the relationship between the availability and use of digital devices in school (e.g. computers) and performance in reading. The PISA 2018 reading test aimed to assess reading literacy in the digital environment while retaining the ability to measure trends in reading literacy over the past two decades.
- A thematic report on "**21st-century readers**" based on PISA 2018 data is being prepared and will provide in-depth analyses of the components of reading literacy required for the 21st century and of students' attitudes and dispositions towards reading both print and digital texts. The resulting evidence and recommendations will aid policy makers, educators and various stakeholders in improving teaching practices and student learning.
- The **PISA 2021** assessment will continue offering the optional **ICT familiarity questionnaire** that will draw on previously administered questions and potentially new item development. Its preparation has been guided by the PISA 2021 ICT framework, that provides a comprehensive strategy to document how students access and use ICT resources in and outside of school, and

to identify how teachers, schools and education systems integrate ICT into pedagogical practices and learning environments. The framework allows for an exploration of how system-level factors influence schools' and students' experiences with ICT, how the availability and use of ICT interact with various teaching practices, and how these associations correlate with students' performance in mathematics, reading and science, and with other outcomes, such as students' ICT skills and well-being.

- The **PISA 2024 "Learning in the Digital World"** assessment is developing a comprehensive framework describing the cognitive, metacognitive and motivational skills that students need to become autonomous learners with digital tools, as well as providing a global measure of students' capacities to engage in self-regulated learning using online technologies. In order to increase the impact of this work, PISA is also planning to develop an online portal that could make a number of digital learning tasks with embedded assessments freely available to educators.
- The **Platform for Innovative Learning Assessments (PILA)** is a new resource for educators looking for engaging and research-based tools to assess their students' growth as autonomous, lifelong learners. A pilot version of the platform is expected to be ready for testing in 2021. PILA tasks use learning analytics to provide insights not just on what students know and can do, but also on how they think and regulate their learning processes. Collecting and interpreting data on how students explore and use resources, experiment with strategies, learn from failures and create their own knowledge in digital environments can reveal a lot about their learning and inform subsequent instruction.
- The OECD **"Skills Outlook 2019: Thriving in a Digital World**" aimed to understand how policies, and in particular those that affect skills development and use, can shape the outcomes of digital transformation and translate into more equally shared benefits among and within countries' populations. One of its chapters focused on the opportunities that technology offers for skills development, in schools, higher education and throughout life. It explored the relationship between technology use in schools and students' performance, teachers' use of new technologies and how policies can unlock the potential of technology for teaching and learning. The Skills Outlook builds on several different pieces of analysis by producing new insights and leveraging evidence produced across the OECD. It integrates comparative data on skills drawing from OECD surveys as well as from other databases.
- The **TALIS 2018 Volume I on "Teachers and School Leaders as Lifelong Learners"** and **Volume II on "Teachers and School Leaders as Valued Professionals"** relied on data from the 2018 cycle of TALIS to explore and examine the various dimensions of teachers' and school leaders' professionalism across education systems. Drawing on the analysis, the report offered policy pointers to consider in designing teacher policies. The provision of tailored support for integrating ICT in teaching and dissemination of good practices was included among the policy pointers and the report presented a snapshot of the use of ICT for teaching and other professional practices (e.g. collaboration), the development of and need for skills related to ICT-use, and resource issues in education systems related to availability of ICT infrastructure.
- The **Teacher Knowledge Survey assessment module** will be an optional module in TALIS 2024. The Teacher Knowledge Survey assessment module will provide information on a) whether teachers are prepared with the knowledge and skills for 21st century teaching, in particular, for using technology to enhance learning, teaching diverse classrooms and for using modern pedagogical approaches and b) the strengths and weaknesses of teachers' current pedagogical knowledge base. Results can be used to improve initial teacher education, teacher induction and continuing professional development to ensure a robust knowledge base in the profession in line with national policy priorities; support policies in attracting and retaining a high-quality teaching workforce; and empower the teaching profession to take charge of its knowledge base.

- The **“Innovative pedagogies for powerful learning”** project aimed to deepen the understanding of innovative teaching and pedagogical approaches that promote students’ engagement and powerful learning, among which pedagogies focusing on the use of new technologies in the classroom. The project developed a framework to analyse innovative pedagogies, a compilation of clusters of innovative pedagogies, and engaged with networks of innovative schools. It also built on desk research and case studies to deepen understanding of innovative pedagogies (how they are implemented, how they work in practice, and how they are taught in teacher education institutions and programmes). The project focused on innovative pedagogies at different levels of education, from ECEC to secondary education. The report “Teachers as Designers of Learning Environments: The Importance of Innovative Pedagogies" (Paniagua and Istance, 2018[27]) was published in 2018.

Annexe B. Data on digital resources in education

Table A B.1. Data mapping from recent OECD surveys

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
Access	PISA (2018)	Computers available for students for educational purposes	Number	Principals	
Access	PISA (2018)	Computers connected to the Internet/World Wide Web (among those available for students for educational purposes)	Number	Principals	
Access	PISA (2018)	Computers that are portable (e.g. laptop, tablet) (among those available for students for educational purposes)	Number	Principals	
Access	PISA (2018)	Interactive whiteboards available in the school altogether	Number	Principals	
Access	PISA (2018)	Data projectors available in the school altogether	Number	Principals	
Access	TALIS (2018)	If the education budget were to increase by 5%, how would teacher rate the importance of the following spending priorities: Investing in ICT	Of low importance / Of moderate importance / Of high importance	Teachers	
Access (home)	PISA (2018)	A computer student can use for school work	Yes	Students	
Access (home)	PISA (2018)	A link to the Internet		Students	
Access (home)	PISA (2018)	Educational software		Students	
Access (home)	PISA (2018)	Number of <Cell phones> with Internet access (e.g. smartphones)	None /One /Two /Three or more	Students	
Access (home)	PISA (2018)	Number of Computers (desktop computer, portable laptop, or notebook)	None /One /Two /Three or more	Students	
Access (home)	PISA (2018)	Number of <Tablet computers> (e.g. <iPad®>, <BlackBerry® PlayBookTM>)	None /One /Two /Three or more	Students	
Access (home)	PISA (2018)	Number of E-book readers (e.g. <KindleTM>, <Kobo>, <Bookeen>)	None /One /Two /Three or more	Students	
Access (teachers)	PISA (2018)	Computers with internet connection available for teachers in the school	Number	Principals	

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
Access, use	PISA (2018)	Devices available to use at home and whether the student uses them: desktop computer, portable laptop or netbook, tablet computer, ebook reader, etc.	Yes/No	Students	
Access, use	PISA (2018)	Devices available to use at school: desktop computer, portable laptop or netbook, tablet computer, ebook reader; interactive whiteboard, etc.	Yes/No	Students	Progressively, the ICT questionnaire in different PISA rounds has adapted the list to include for instance new devices.
Competencies/ self-efficacy / skills	PIAAC (2012, 2015, 2017)	Problem solving in technology-rich environments	PIAAC proficiency score	Teachers	The assessment problem solving in technology-rich environments as "using digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks
Competencies/ self-efficacy / skills	TALIS (2018)	Extent to which teacher can: Support student learning through the use of digital technology (e.g. computers, tablets, smart boards)	Not at all/ To some extent / Quite a bit / A lot	Teachers	
Digital competence (teaching)	PISA (2018)	Whether at school, between <grade 1 of ISCED 1> and today, has been taught: How to use keywords when using a search engine such as <Google©>, <Yahoo©>, etc.	Yes/No	Students	
Digital competence (teaching)	PISA (2018)	Whether at school, between <grade 1 of ISCED 1> and today, has been taught: How to decide whether to trust information from the Internet	Yes/No	Students	
Digital competence (teaching)	PISA (2018)	How to compare different web pages and decide what information is more relevant for your school work	Yes/No	Students	
Digital competence (teaching)	PISA (2018)	To understand the consequences of making information publicly available online on <Facebook©>, <Instagram©>, etc.	Yes/No	Students	
Digital competence (teaching)	PISA (2018)	How to use the short description below the links in the list of results of a search	Yes/No	Students	

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
Digital competence (teaching)	PISA (2018)	How to detect whether the information is subjective or biased	Yes/No	Students	
Digital competence (teaching)	PISA (2018)	How to detect phishing or spam emails	Yes/No	Students	
Digital competence (teaching)	PISA (2018)	In lessons, has taught: How to decide whether to trust information from the Internet	Yes/No	Teachers	
Digital competence (teaching)	PISA (2018)	In lessons, has taught: How to compare different web pages and decide what information is more relevant for the students' school work	Yes/No	Teachers	
Digital competence (teaching)	PISA (2018)	In lessons, has taught: To understand the consequences of making information publicly available online on <Facebook©>, <Instagram©>, etc.	Yes/No	Teachers	
Digital competence (teaching)	PISA (2018)	In lessons, has taught: How to use the short description below the links in the list of results of a search	Yes/No	Teachers	
Digital competence (teaching)	PISA (2018)	In lessons, has taught: How to detect whether the information is subjective or biased	Yes/No	Teachers	
Digital competence (teaching)	PISA (2018)	In lessons, has taught: How to detect phishing or spam emails	Yes/No	Teachers	
Digital competence (teaching)	PISA (2018)	Teach the following aspects of reading comprehension: Assessing credibility of information available on the Internet	Never or almost never / Some lessons / Many lessons / Every lesson or almost every lesson	Teachers	
Digital competence (teaching)	PISA (2018)	Teach the following aspects of reading comprehension: Searching and selecting relevant information on the Internet	Never or almost never / Some lessons / Many lessons / Every lesson or almost every lesson	Teachers	
School guidelines and practices for the use of digital devices	PISA (2018)	School has: Its own written statement about the use of digital devices	Yes/No	Principals	
School guidelines and practices for the use of digital devices	PISA (2018)	School has: Its own written statement specifically about the use of digital devices for pedagogical purposes	Yes/No	Principals	
School guidelines and practices for the use of digital devices	PISA (2018)	School has: A programme to use digital devices for teaching and learning in specific subjects	Yes/No	Principals	

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
School guidelines and practices for the use of digital devices	PISA (2018)	School has: Regular discussions with teaching staff about the use of digital devices for pedagogical purposes	Yes/No	Principals	
School guidelines and practices for the use of digital devices	PISA (2018)	School has: A specific programme to prepare students for responsible internet behaviour	Yes/No	Principals	
School guidelines and practices for the use of digital devices	PISA (2018)	School has: A specific policy about using social networks (<Facebook>, etc.) in teaching and learning	Yes/No	Principals	
School guidelines and practices for the use of digital devices	PISA (2018)	School has: A policy concerning the use of digital devices for teaching	Yes/No	Teachers	
School guidelines and practices for the use of digital devices: teachers' use	PISA (2018)	School has: A specific programme to promote collaboration on the use of digital devices among teachers	Yes/No	Principals	
School guidelines and practices for the use of digital devices: teachers' use	PISA (2018)	School has: Scheduled time for teachers to meet to share, evaluate or develop instructional materials and approaches that employ digital devices	Yes/No	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	The number of digital devices connected to the Internet is sufficient (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	The school's Internet bandwidth or speed is sufficient (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	The number of digital devices for instruction is sufficient (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	Digital devices at the school are sufficiently powerful in terms of computing capacity (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	The availability of adequate software is sufficient (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	Teachers have the necessary technical and pedagogical skills to integrate digital devices in instruction (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	Teachers have sufficient time to prepare lessons integrating digital devices (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	Effective professional resources for teachers to learn how to use digital devices are available (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	An effective online learning support platform is available (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	Teachers are provided with incentives to integrate digital devices in their teaching (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	PISA (2018)	The school has sufficient qualified technical assistant staff (Extent to which agree with this statement about school's capacity to enhance learning and teaching using digital devices)	Strongly disagree/ Disagree/ Agree/ Strongly agree	Principals	
School's capacity to enhance teaching and learning using digital devices	TALIS (2018)	The school's capacity to provide quality instruction is currently hindered by the following issues: Shortage or inadequacy of digital technology for instruction (e.g. software, computers, tablets, smart boards	Not at all / To some extent / Quite a bit / A lot	Principals	
School's capacity to enhance teaching and learning using digital devices	TALIS (2018)	The school's capacity to provide quality instruction is currently hindered by the following issues: Insufficient Internet access	Not at all / To some extent / Quite a bit / A lot	Principals	
TPL	PIAAC (2012, 2015, 2017)	Report need for further training to do one's job	Yes/No	Teachers	
TPL	TALIS (2018)	Use of ICT for teaching included in teachers' formal education and training	Yes/No	Teachers	
TPL	TALIS (2018)	Teachers' sense of preparedness for using ICT in teaching after formal education and training	Not at all/ Somewhat / Well /Very well	Teachers	

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
TPL	TALIS (2018)	Part of induction when began work at this school: Online courses/seminars	Yes/No	Teachers	
TPL	TALIS (2018)	Part of induction when began work at this school: Online activities (e.g. virtual communities)	Yes/No	Teachers	
TPL	TALIS (2018)	During the last 12 months, participated in the following professional development activities: Online courses/seminars	Yes/No	Teachers	
TPL	TALIS (2018)	Topic included professional development activities during the last 12 months: ICT (information and communication technology) skills for teaching	Yes/No	Teachers	
TPL	TALIS (2018)	Extent to which currently need professional development in: ICT (information and communication technology) skills for teaching	No need at present / Low level of need / Moderate level of need / High level of need	Teachers	
TPL	PISA (2018)	ICT skills for teaching included in teacher education or training programme	Yes/No		
TPL	PISA (2018)	ICT skills for teaching included in other professional qualification and your professional development activities	Yes/No	Teachers	
TPL	PISA (2018)	Need professional development in: ICT skills for teaching	No need at present / Low level of need / Moderate level of need / High level of need	Teachers	
TPL	PISA (2018)	In lessons, has taught: How to use keywords when using a search engine	Yes/No	Teachers	
TPL (principals)	TALIS (2018)	Need professional development in: Using data for improving the quality of the school	No need at present / Low level of need / Moderate level of need / High level of need	Principals	
TPL (using technology)	TALIS (2018)	During the last 12 months, participated in the following professional development activities aimed at the respondent as a principal: Online courses/seminars	Yes/No	Principals	
TPL (using technology)	TALIS (2018)	Provisions included in teachers' induction at this school: Online courses/ seminars	Yes/No	Teachers	
TPL (using technology)	TALIS (2018)	Provisions included in teachers' induction at this school: Online activities (e.g. virtual communities)	Yes/No	Teachers	

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
Use	PISA (2018)	Amount of time spent using the Internet at school during a typical weekday	No time - More than 6 hours a day	Students	Progressively, the ICT questionnaire in different PISA rounds has adapted the list to include for instance new devices.
Use	PISA (2018)	Amount of time spent using digital devices during classroom lessons, by subject (e.g. test language lessons, science, mathematics)	No time - More than 60 minutes a week	Students	
Use	PISA (2018)	Amount of time spent using digital devices outside of classroom lessons (regardless whether at home or in school), by subject (e.g. test language lessons, science, mathematics)	No time - More than 60 minutes a week	Students	
Use	PISA (2018)	Within the last month, a digital device has been used for learning or teaching during lessons, by subject (e.g. test language lessons, science, mathematics)	Yes, both the teacher and students used it / Yes, but only students use it / Yes, but only the teacher used it / No	Students	
Use	PISA (2018)	Use of digital devices for the following school work activities outside of school (schoolwork related): browsing the Internet for schoolwork, browsing the Internet to follow up lessons, using email for communication with teachers and submission of homework, etc.	Never or hardly ever - Every day	Students	
Use	PISA (2018)	Use of digital devices for the following school work activities outside of school: playing one -player games, chatting online, participating in social networks, etc.	Never or hardly ever - Every day	Students	
Use	PISA (2018)	Use of digital devices at school for: chatting, browsing the Internet for schoolwork, posting work on the school's website, doing homework on a school computer, etc.	Never or hardly ever - Every day	Students	
Use	TALIS (2018)	Frequency with which teacher: lets students use ICT (information and communication technology) for projects or class work	Never or almost never / Occasionally / Frequently / Always	Teachers	

Area	Source	Indicator/ variable	Values	Collected at the level of	Comments
Use	PISA (2018)	How often use following tools in teaching this year: Tutorial software or practice programmes, digital learning games, word-processors or presentation software, spreadsheets, multimedia production tools, concept mapping software, data logging and monitoring tool, simulations and modelling software, social media, communication software, computer-based information resources (e.g. websites, wikis), interactive digital learning resources, graphing, e-portfolios	Never / In some lessons / In most lessons / In every or almost every lesson	Teachers	
Use (teachers)	PIAAC (2012, 2015, 2017)	Intensity of ICT use at work	Median intensity	Teachers	Indicator based on tasks associated with ICT use at work (e.g. reading and writing emails, using word-processing or spreadsheet software, programming

Note: The ICT familiarity questionnaire and the teacher questionnaire are optional in PISA (2018).