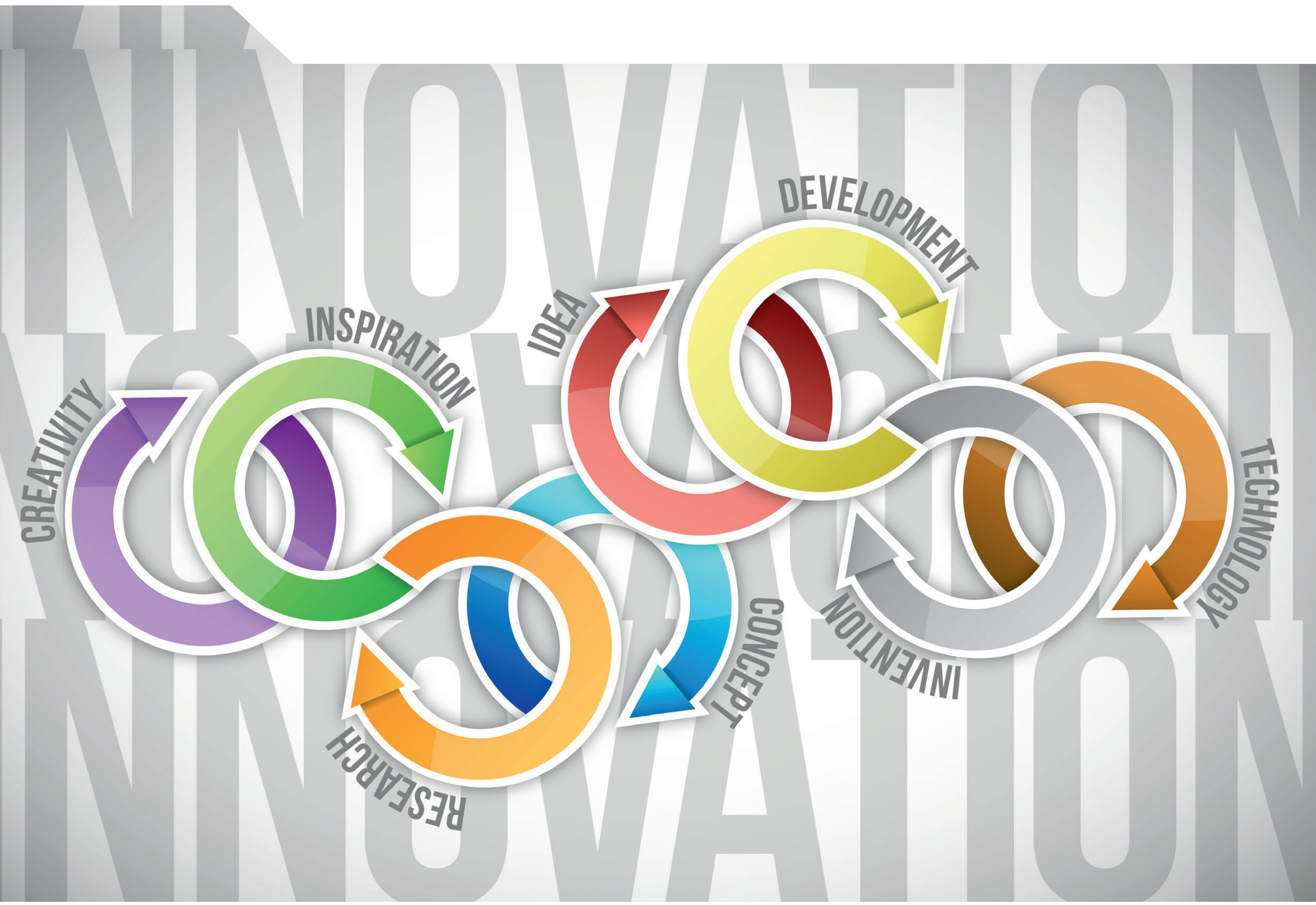
Education Innovation and Research

Innovating Education and Educating for Innovation

THE POWER OF DIGITAL TECHNOLOGIES AND SKILLS



Centre for Educational Research and Innovation

OECD

Educational Research and Innovation

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THE POWER OF DIGITAL TECHNOLOGIES AND SKILLS

OECD
BETTER POLICIES FOR BETTER LIVES

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Foreword

Digital technologies have a profound impact on economies and societies and are changing the way we work, communicate, engage in social activities and enjoy ourselves. They also drive innovation in many different spheres of life. The innovative capacity of technology is very much conditioned by the level of digital skills of the population. No wonder there is a very strong correlation between education and skills and the uptake and use of digital technologies in various spheres of life. The role of education and skills in promoting innovation is critical.

Yet, despite the huge potential of digitalisation for fostering and enhancing learning, the impact of digital technologies on education itself has been shallow. Massive investments in ICT (Information and Communication Technology) in schools have not yet resulted in the hoped for transformation of educational practices, probably because the overriding focus on hardware and connectivity has kept back equally powerful strategies for increasing teachers' ICT skills, improving teachers' professional development, reforming pedagogies and producing appropriate software and courseware.

Discussions about the potential of digital technologies in education today increasingly place the issue as part of a more comprehensive approach to innovation in education. Education systems and institutions are not averse to change in themselves, but there seem to be very powerful barriers in place that prevent digital technologies from reaching their potential in educational institutions and teaching and learning practices.

Innovation doesn't happen in a vacuum, but requires openness and interactions between systems and their environments. This is also very much the case for education. Schools cannot be left alone to make the difficult process of transformation, but need support not only through policies, but also from other actors and stakeholders. In recent years the emergent education industry has taken on a very important role. This role is not simply defined by commercial corporate interests selling products and services to schools, but is increasingly framed into a much wider concern for genuine innovation.

In order to foster a dialogue aiming to identify the best policies and practices to foster innovation in education, the Global Education Industry Summits brings together governments and leaders from the global education industry. The success of these summits very much depends on the evidence that can feed into the dialogue. That is why the OECD, as a global leader in internationally comparative data and analysis, has produced this synthesis of the available evidence, generated through its surveys and analytical work. It serves as a background document for the second Global Education Industry Summit in Jerusalem on 26-27 September 2016.

The report was prepared by Dirk Van Damme, head of the OECD Centre for Educational Research and Innovation (CERI), compiling analyses from recent OECD publications on innovation, innovation in education and technology-based innovation. In particular, the report offers a synthesis of the outcomes of different recent CERI projects, notably CERI's "Innovation Strategy for Education and Training", "Innovative Learning Environments", and "Open Education Resources". It also draws on recent publications of other programmes of the Directorate for Education and Skills (notably the OECD Programme on International Student Assessment (PISA), the OECD Programme for the International Assessment of Adult Competencies (PIAAC), the Teaching and Learning International

Survey (TALIS) and from some other OECD reports. Particular acknowledgment should be given to a forthcoming CERI publication on business-driven innovation in education, in particular to the analyses of markets and innovation in the education industry by Vincent-Lancrin, Atkinson and Kärkkäinen (Chapter 5) and business-driven innovation in education by Foray and Raffo (Chapter 6).

Other sources for the report are the following OECD publications: OECD Skills Outlook 2013: First Results from the Survey of Adult Skills (2013); Sparking Innovation in STEM Education with Technology and Collaboration: A Case Study of the HP Catalyst Initiative, OECD Education Working Papers, No. 91 (2013); Measuring Innovation in Education. A New Perspective (2014); Innovation, governance and reform in education. CERI Conference background paper (2014); Measuring the Digital Economy: A New Perspective (2014); Digital Economy Outlook (2015); The Innovation Imperative: Contributing to Productivity, Growth and Well-being (2015); E-Learning in Higher Education in Latin America (2015); Adults, Computers and Problem Solving: What's the Problem? (2015); Students, Computers and Learning. Making the Connection (2015); Education at a Glance 2015: OECD Indicators (2015); Open Educational Resources: A Catalyst for Innovation (2015); Schooling Redesigned. Towards Innovative Learning Systems (2015); Skills Matter: Further Results from the Survey of Adult Skills (2016); Getting Skills Right: Assessing and Anticipating Changing Skill Needs (2016); and Skills for a Digital World (2016).

Use has also been made of various issues of the Education Indicators in Focus (http://dx.doi.org/10.1787/22267077), PISA in Focus (http://dx.doi.org/10.1787/22260919), and Teaching in Focus (http://dx.doi.org/10.1787/23039280) series, as well as OECD Education Today blog posts (http://oecdeducationtoday.blogspot.fr/), OECD Education Working Papers (www.oecd-ilibrary.org/education/oecd-education-working-papers_19939019) and unpublished documents. Other sources have been referred to in the text.

Rachel Linden co-ordinated production of the report.

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Executive summary

This background report to the second Global Education Industry Summit, held in Jerusalem on 26-27 September 2016, covers the available evidence on innovation in education, the impact of digital technologies on teaching and learning, and the role of digital skills and the education industries in the process of innovation, using data from OECD surveys. The overall aim of the summit was to bring together ministers of education and industry leaders to start a dialogue on policies and strategies to foster innovation in education.

As in all sectors, innovation will be essential to bring about qualitative changes in education, as opposed to the quantitative expansion seen so far. These changes are needed to increase efficiency and improve the quality and equity of learning opportunities. Although education is not a change-averse sector, with improvements already taking place in classrooms, it has not managed to harness technology to raise productivity, improve efficiency, increase quality and foster equity in the way other public sectors have. At the same time education can also foster innovation in society at large by developing the right skills to nurture it. These skills, including critical thinking, creativity and imagination, can be fostered through appropriate teaching, and practices such as entrepreneurship education. Governments should develop smart innovation strategies for education with the right policy mix to give meaning and purpose to innovation, including creating an innovation-friendly culture.

The steep increase in the use of digital devices and the Internet with increasing levels of education shows that education matters in the uptake of digital technologies. This has huge implications for the role of education systems in equipping individuals with the skills they need to benefit from new technology. The "digital divide" has become a skills gap between the haves and have-nots. Digital skills generate a significant return in terms of employment, income and other social outcomes for those who have them, but set up barriers to better life opportunities for those without.

In recent years governments have invested heavily in information and communications technology (ICT) in schools. The quality of schools' educational resources, including ICT and connectivity, has increased greatly in recent years. However, international surveys have found that digital technologies have not yet been fully integrated in teaching and learning. Teachers do not feel sufficiently skilled to use ICT effectively, at best using digital technologies to complement prevailing teaching practices. As tertiary-educated professionals, teachers have relatively good ICT skills, but these fall off sharply with age, especially among the large cohort of older teachers.

Analysis of the Programme for International Student Assessment (PISA) data on the effects of ICT on students' outcomes adds to the sobering picture. The introduction of digital technologies in schools has not yet delivered the promised improvements of better results at lower cost. There is only a weak, and sometimes negative, association between the use of ICT in education and performance in mathematics and reading, even after accounting for differences in national income and socio-economic status.

Part of the explanation for this limited success lies in the focus on technology and connectivity among both suppliers and policy makers. Schools and education systems are not yet ready to realise technology's potential. Gaps in the digital skills of both teachers and students, difficulties in locating high-quality digital learning resources and software, a lack of clarity over learning goals, and insufficient pedagogical preparation on how to blend technology meaningfully into teaching, have driven a wedge between expectations and reality. Schools and governments must address these challenges or technology may do more harm than good.

Although they cannot transform education by themselves, digital technologies do have huge potential to transform teaching and learning practices in schools and open up new horizons. The challenge of achieving this transformation is more about integrating new types of instruction than overcoming technological barriers. Digital technology can facilitate:

- Innovative pedagogic models, for example based on gaming, online laboratories and real-time assessment, which have been shown to improve higher-order thinking skills and conceptual understanding and in many cases have enhanced students' creativity, imagination and problem-solving skills.
- Simulations such as remote or virtual online laboratories, providing relatively low-cost flexible access to experiential learning.
- International collaborations, overcoming barriers of geography and formal classroom hours. These give students insight into other cultures and experience multicultural communication, and closely emulate the collaborative nature of today's professional environments.
- Real-time formative assessment and skills-based assessments, allowing teachers to monitor student learning as it happens and adjust their teaching accordingly. It may also enable the active participation of more students in classroom discussions. Technology-supported assessment enables skill development to be monitored in a more comprehensive way than is possible without technology.
- E-learning, open educational resources and massive open online courses, mainly aimed at autonomous learners.

Technology-based innovations in education reshape the environments in which schools operate. In general, they tend to open up learning environments, both to the digital world and the physical and social environment. They also bring new actors and stakeholders into the educational system, not least the education industries, with their own ideas, views and dreams about what the future of education can hold. Despite fears of "marketisation", the education industry could be an essential partner in any education innovation strategy. Instead of being considered just as providers of goods and services, different relationships between schools and industry could foster an innovation-friendly environment, with a greater focus on methods over technologies.

Understanding the education industries better, including their market structures and innovation processes, would help to create a more mature relationship with the education sector. Innovation in the industry – which develops the products and services that could drive innovation in schools – does not happen in isolation from what is happening in the education sector. Only when there is an innovation-friendly culture in education systems, supported by an innovation-friendly business environment and policies, will industries start to engage in risk-intensive research and development. Governments can support this by fostering a climate of entrepreneurship and innovation in education.

Innovating Education and Educating for Innovation
The Power of Digital Technologies and Skills

Chapter 1

The innovation imperative in education

Education is sometimes perceived as a sector which is resistant to change, while at the same time it faces a crisis of productivity and efficiency. Innovation could help improve the quality of education, as well as provide more "bang for the buck" in times of budget pressures and rising demand.

This chapter considers what is meant by innovation in the context of the education sector, and how best it can be measured. Using data from international surveys, it finds that education is more innovative in some ways than other sectors and that there has been innovation across all countries, particularly in teaching methods. It considers what skills are needed to encourage innovation more widely in the economy and whether schools and universities are helping students develop those skills. Finally, it looks at national and international strategies covering innovation in education and beyond.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Innovation in education: why and what

Innovation in education: the sense of urgency

Innovation in education is a highly contentious issue. Talking to education ministers one quickly gets the impression that education systems in general are very reluctant to innovate, and that there is strong resistance to change among teachers. Education is sometimes perceived as one of the most conservative social systems and public policy fields. But talking to teachers gives one the opposite idea – that there are too many changes imposed on them without much consultation or the necessary preconditions for successfully implementing change. In some countries, innovative change has been implemented without the care and diligence needed or the appropriate prior testing, experimentation and evaluation.

This controversy should not deter us from looking to the facts. And the facts clearly demonstrate that education systems are running up against very serious problems which, if left untouched, could result in serious risks not only for education itself but also for future economic growth, social progress and well-being. Since the mid-20th century, education systems have expanded enormously and human populations have never been more highly educated than today. Emerging economies and developing countries are now also relentlessly expanding their education systems, seeing education as an indispensable ingredient of modernisation and progress. Indeed, the benefits to individuals and societies of ever more education remain very impressive. Yet, although many policy makers may consider the continued expansion in numbers as the best route forward, a closer look into the data reveals that this may as well lead us into difficulties.

The problem education is facing is mainly one of productivity and efficiency. Here, efficiency means the balance between resources invested and the outcomes in terms of students' performance and equity. Over the past decades ever more resources have been invested in education. Looking just at school education, the average expenditure per student across OECD countries increased by no less than 17% between 2005 and 2013 in constant prices (OECD, 2016). But over roughly the same period, the Programme for International Student Assessment (PISA) data from the 2003 and 2012 surveys show no significant improvement in test scores. Instead, in most countries the percentage of top performers has declined. And, while the PISA data show some progress in equity, huge gaps remain in equality of opportunity and education outcomes between various social groups (OECD, 2013).

The problem of productivity and efficiency in education is even more striking when education is compared with other public policy sectors, which have realised enormous productivity gains in past decades. In sectors such as health, technology has been a major driver of increased productivity and efficiency with much improved outcomes even if the cost has also gone up. Many observers wonder why enormous advances in technology has not yet led to similar improvements in education. Governments have invested a lot in bringing technology, mainly information and communications technology (ICT), to schools. But, as the analysis of PISA data discussed in Chapter 3 will show, it has not yet been possible to associate increased availability and use of computers in schools with improvements in learning outcomes.

This book argues that innovation in education – as in all sectors of the economy and society – is imperative to bring about qualitative changes, in contrast to the mere quantitative expansion that we have seen so far. This will lead to more efficiency and improved outcomes in quality and equity of learning opportunities.

Innovation in education as part of innovation in economies and societies

In the last few decades, innovation in general has been increasingly regarded as a crucial factor in maintaining competitiveness in a globalised economy. Innovation can breathe new life into slowing stagnant markets, and act as a mechanism to enhance any organisation's ability to adapt to changing environments (Damanpour and Gopalakrishnan, 1998; Hargadon and Sutton, 2000). Both policies and theories on innovation have mainly focused on the business sector (Lekhi, 2007). Businesses need to innovate in order to keep up with their competition by introducing new products or services, improving the efficiency of their production processes and organisational arrangements, or enhancing the marketing of their activities in order to guarantee their survival.

Much more recently, policy interest has extended this "innovation imperative" from private organisations to the provision of public services. Although public services, including education, tend neither to operate within competitive markets nor have the same incentives to innovate as businesses do (Lekhi, 2007), there are important arguments to push for innovation in education to maximise the value of public investment (Box 1.1). Several recent national innovation strategies include provisions for more innovation in the public sector (such as Australia, Finland, the Netherlands, Norway and the United Kingdom). Demographic pressures, burgeoning demand for government services, higher public expectations and ever-tighter fiscal constraints mean that the public sector needs innovative solutions to enhance productivity, contain costs and boost public satisfaction.

Innovation in the public sector in general, and in education in particular, could be a major driver for significant welfare gains. Governments provide a large number of services in OECD countries and these services account for a considerable share of national income. Government expenditure in OECD countries represents about 48% of gross domestic product (GDP) on average, and in some cases corresponds to more than half of national GDP. Education is a major component of government services: in 2012, public expenditure on educational institutions accounted for 5.3% of national income on average for OECD countries (OECD, 2015b). Innovations to improve the effectiveness and efficiency of such a large area of government spending could yield important benefits.

Why innovation in education matters

How could innovation add value in the case of education? First of all, educational innovations can improve learning outcomes and the quality of education provision. For example, changes in the educational system or in teaching methods can help customise the educational process. New trends in personalised learning rely heavily on new ways of organising schools and the use of ICT.

Second, education is perceived in most countries as a means of enhancing equity and equality. Innovations could help enhance equity in the access to and use of education, as well as equality in learning outcomes.

Box 1.1. **Policy messages from the OECD's Innovation Imperative**

Policy makers can do better to marshal the power of innovation to help achieve core public policy objectives. Strong leadership at the highest political levels will be essential.

There is no silver bullet: policy makers will require a mix of policies for innovation, which will vary depending on the context, and have to go beyond narrowly defined research and innovation policies.

Governments can foster more innovative, productive and prosperous societies, increase well-being, and strengthen the global economy by concentrating their policies on five concrete areas:

Effective skills strategies: innovation rests on people with the knowledge and skills to generate new ideas and technologies, bring them to the market, and implement them in the workplace, and who are able to adapt to structural changes across society. But two out of three workers do not have the skills to succeed in a technology-rich environment. A broad and inclusive education and skills strategy is therefore essential.

A sound, open and competitive business environment: the environment should encourage investment in technology and in knowledge-based capital; enable innovative firms to experiment with new ideas, technologies and business models; and help successful firms to grow and reach scale. Policy should avoid favouring incumbents as this reduces experimentation, delays the exit of less productive firms and slows the reallocation of resources from less to more innovative firms.

Sustained public investment in an efficient system of knowledge creation and diffusion: most of the key technologies in use today, including the Internet and genomics, have their roots in public research, illustrating how essential public investments are. At a time when the world economy faces many long-term challenges, public investment needs to focus on durable benefits, rather than short-term outcomes. Support for business innovation should be well balanced and not overly reliant on tax incentives. Incentives should be complemented with well-designed, competitive grants which can be better suited to the needs of young innovative firms, and can also be focused on the areas with the highest impact.

Increased access and participation in the digital economy: digital technologies offer a large potential for innovation, growth and greater well-being. However, policy action is needed to preserve the open Internet, address privacy and security concerns, and ensure access and competition. Digitally enabled innovation requires investment in new infrastructure such as broadband, but also in ensuring there will be enough spectrum and Internet addresses for the future.

Sound governance and implementation: the impact of policies for innovation depends heavily on their governance and implementation, including trust in government action and a commitment to learning from experience. Policy learning rests on a well-developed institutional framework, strong capabilities for evaluation and monitoring, the application of identified good practices, and an efficient, capable and innovative public sector.

Source: OECD (2015a), *The Innovation Imperative: Contributing to Productivity, Growth and Well-Being*, *http://dx.doi.org/10.1787/9789264239814-en*.

Third, public organisations are often under as much pressure as businesses to improve efficiency, minimise costs and maximise the "bang for the buck". Mulgan and Albury (2003) argue that there has been a tendency for costs in all public services to rise faster than those in the rest of the economy, and education is no exception. While this could be attributed to Baumol's "cost disease" (see Chapter 6), inherent to any public-service provision which faces ever-rising labour costs and limited scope for transformative productivity gains, this may also be due to a lack of innovation, (Foray and Raffo, 2012). Innovation, then, could stimulate more efficient provision of these services.

Finally, education should remain relevant in the face of rapid changes to society and the national economy (Barrett, 1998: 288). The education sector should therefore introduce the changes it needs to adapt to societal needs. For example, education systems need to adopt teaching, learning or organisational practices that have been identified as helping to foster "skills for innovation" (Dumont et al., 2010; Schleicher, 2012; Winner et al., 2013). The results from PISA, as well as the Trends in International Mathematics and Science Study (TIMSS), Progress in International Reading Literacy Study (PIRLS) and the OECD Survey on Adult Skills point to the need for innovation to improve results in literacy, numeracy or scientific literacy in many countries.

Defining innovation in education

Although the terms are often used interchangeably, it is important to distinguish innovation from reform and change (Figure 1.1). Most of the literature defines innovation as the implementation not just of new ideas, knowledge and practices but also of improved ideas, knowledge and practices (Kostoff, 2003; Mitchell, 2003). Innovation is thus different from reform or change, which do not necessarily mean the application of something new, nor do they imply the application of improved ideas or knowledge (King and Anderson, 2002).

Huerta Melchor (2008) suggests that reform is only one way of producing change; it implies a special approach to problem solving. Sometimes changes in organisations are key parts of a reform but other reforms may produce little or no change. Change may be an intended or unintended phenomenon, whereas reform is a structured and conscious process of producing change, no matter its extent. Reforms can occur in political, economic, social and administrative domains and contain ideas about problems and solutions and are typically understood as initiatives driven from the top of a system or organisation.

Many definitions of innovation are used in different contexts and disciplines although for statistical purposes, the most widely accepted definition of innovation comes from the Oslo Manual (OECD/Eurostat, 2005). This defines innovation as "the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (see Box 1.2). In this definition, implementation refers to the introduction of a product to the market, or the actual use of processes, marketing methods and organisational methods.

Box 1.2. **OECD definitions of innovation**

The current edition of the Oslo Manual identifies four types of innovation:

Product innovation: the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

Process innovation: the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.

Marketing innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion, or pricing.

Organisational innovation: the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

Source: OECD-Eurostat (2005), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd Edition, *http://dx.doi.org/10.1787/9789264013100-en*.

This definition has been widely applied to the private sector and can also be applied to education with small modifications. Educational organisations such as schools, universities, training centres, or education publishers could introduce 1) new products and services, such as a new syllabus, textbooks or educational resources; 2) new processes for delivering their services, such as the use of ICT in e-learning services; 3) new ways of organising their activities, such as ICT to communicate with students and parents; or 4) new marketing techniques, e.g. differential pricing of postgraduate courses. These new practices are intended to improve the provision of education in one way or another, and therefore should be regarded as improvements.

However, the notion of "improvement" in many public services, including education, can be elusive and the use of this definition has been challenged. The perception of improvement depends on the perspective of the stakeholders, who may wear several hats: consumer, citizen and taxpayer. Assessing the success of companies in the private sector by profit, sales or growth is widely accepted: ultimately they have a single bottom line which prevails over any other objectives. By contrast, whether public organisations stay in business or close is usually a political decision rather than a market sanction. Public organisations are assessed on multiple objectives, such as increased quality, equity, coverage and efficiency, which are less commensurable and can even conflict with each other.

As a result, improvements in education can be perceived differently depending on which objective is examined or on the point of view of the observer. Moreover, cultural values, social policies and political goals can mean countries prioritise these objectives differently. Priorities can also change over time as circumstances and citizens' expectations change. This has consequences for the validity and limitations of the indicators that need to be gathered. Ideally, innovation indicators in the education sector should be linked to specific social and educational objectives such as learning outcomes, cost efficiency, equity or public satisfaction. Innovation should also be measured at different levels and, where no objective measurement can be made, according to different stakeholders' perspectives.

Figure 1.1. **Comparing innovation, reform and change**

	Innovation	Reform	Change
Definition	Implementation of improved ideas, knowledge and practices	Structured and conscious process of producing change	Transformation or alteration that may be an intended or unintended phenomenon
Key characteristics	Implies novelty and brings benefits	Produces change (though in some cases only little or none)	Is historical, contextual and processual
Types	Process, product, marketing or organisational Incremental, radical or systemic in form	Radical, incremental or systemic	Differentiated by pace (continuous or episodic) and scope (convergent or radical)

Source: Cerna, L. (2014), "Innovation, governance and reform in education", CERI Conference background paper, 3-5 November 2014, *www.oecd.org/edu/ceri/CERI%20Conference%20Background%20Paper_formatted.pdf*.

Measures of innovation in education

Innovation in education: a measurement challenge

The measurement of innovation and its effectiveness in the public sector – and in education in particular – is in its infancy. Recent work on the framework of the Innovation Strategy project of the OECD's Centre for Educational Research and Innovation (CERI), reported in *Measuring Innovation in Education* (OECD, 2014a) provides new measures of the readiness of education to innovate. *Measuring Innovation in Education* is a pioneering attempt to provide indicators based on existing international datasets. It aims to provide education policy makers with an estimated order of magnitude of innovation and change in education. It offers two broad approaches to measuring innovation in education: 1) assessing the perceptions of recent tertiary graduates, including those working in education, about innovation in their workplace; and 2) analysing organisational changes through teacher-student surveys.

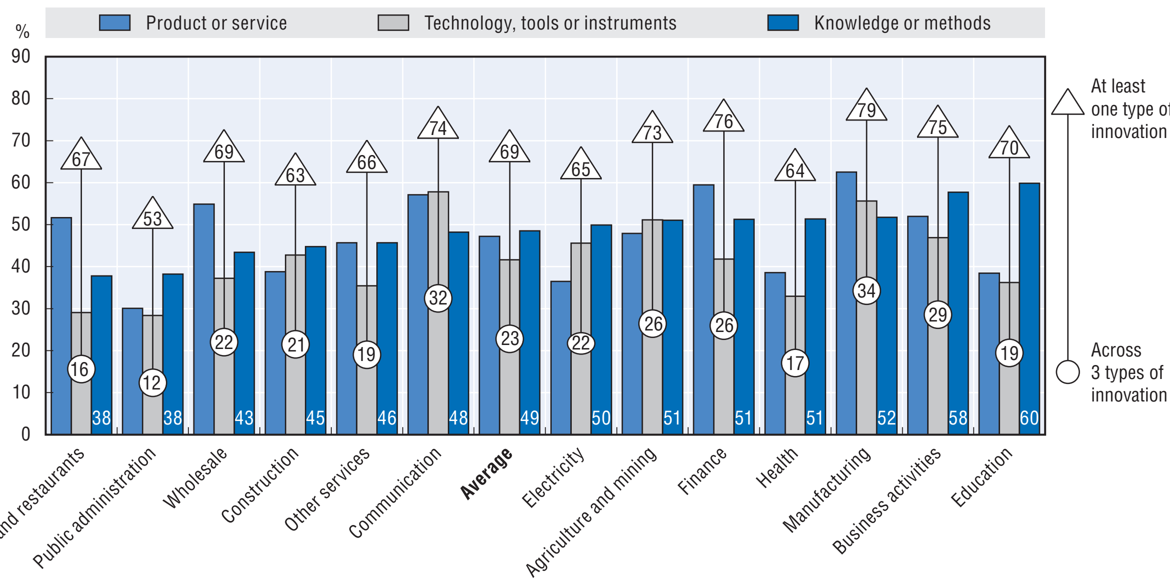
Do education professionals perceive their workplaces to be innovative?

The first approach – asking graduates to assess the "level" of innovation – is subjective but it provides information on the perceived level of innovation by sector. Based on two surveys covering 19 European countries – the 2005 Research into Employment and Professional Flexibility (REFLEX) and the 2008 Higher Education as a Generator of Strategic Competences (HEGESCO) – the project developed a measure of innovation in education compared with other professional sectors. These surveys defined innovation as the introduction of "new or significantly improved products, processes, organisation or marketing methods". They asked tertiary graduates, five years after they graduated: "How would you characterise the extent of innovation in your organisation or your workplace?" in reference to three types of innovation identified in the Oslo Manual (OECD/Eurostat, 2005): 1) products or services (such as new syllabuses, textbooks or educational resources); 2) technology, tools or instruments (new processes for delivering services such as use of ICT in e-learning services, new learning-management systems, new online courses, or new pedagogic tools, such as maps, anatomy models, e-labs); and 3) knowledge or methods (such as new pedagogies, new administrative management systems for admissions or other formalities, or the use of ICT to communicate with students and parents). On a scale of 1 (very low) to 5 (very high), "High innovation" corresponded to scores of 4 and 5. The indicators presented below capture innovation as a significant change in key practices.

Contrary to common belief, the results suggest that there is a fair level of innovation in the education sector, both in absolute terms and relative to other sectors. On average, more than two-thirds of tertiary graduates (69%) across all sectors perceived their workplace to be highly innovative for at least one type of innovation. Interestingly, about the same proportion of tertiary graduates employed in the education sector (70%), both public and private, considered their workplace to be highly innovative for at least one type of innovation. The most common innovation reported in the education sector was in knowledge and methods: 59% of tertiary graduates employed in the education sector considered their workplace to be highly innovative in that respect compared to 49%, on average, across all sectors (Figure 1.2). In contrast, 38% considered their workplace to be highly innovative regarding products or services (compared with 47% on average) and 36% considered their workplace as highly innovative regarding technology, tools or instruments (compared with 41% on average).

Figure 1.2. **Professionals in highly innovative workplaces, by sector and innovation type**

Percentage of graduates working in workplaces perceived as highly innovative, 2005 or 2008



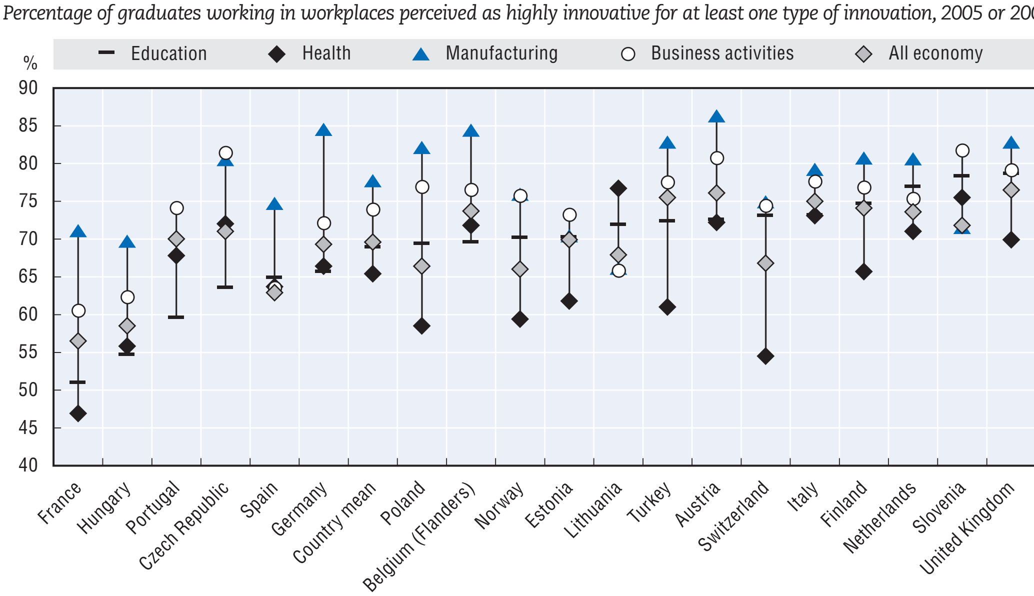
Data are ranked in ascending order of the percentage of graduates working in perceived highly innovative workplaces for knowledge or methods innovation.

Source: Figures 1.4, 1.6 and 1.8 from OECD (2014), *Measuring Innovation in Education: A New Perspective*, Educational Research and Innovation, OECD Publishing. *http://dx.doi.org/10.1787/9789264215696-en*

StatLink http://dx.doi.org/10.1787/888933283508

Figure 1.3. **Professionals in highly innovative workplaces, by sector and country**

Percentage of graduates working in workplaces perceived as highly innovative for at least one type of innovation, 2005 or 2008



Data are ranked in ascending order of the percentage of graduates who perceive their workplace in education sector to be highly innovative regarding at least one type of innovation.

Notes: Hungary, Lithuania, Poland, Slovenia and Turkey refer to HEGESCO (2008). Austria, Belgium Flemish Community, Czech Republic, Estonia, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Switzerland, and United Kingdom refer to REFLEX (2005).

Source: Figure 1.5 from OECD (2014), *Measuring Innovation in Education: A New Perspective*, Educational Research and Innovation, OECD Publishing. *http://dx.doi.org/10.1787/9789264215696-en.*

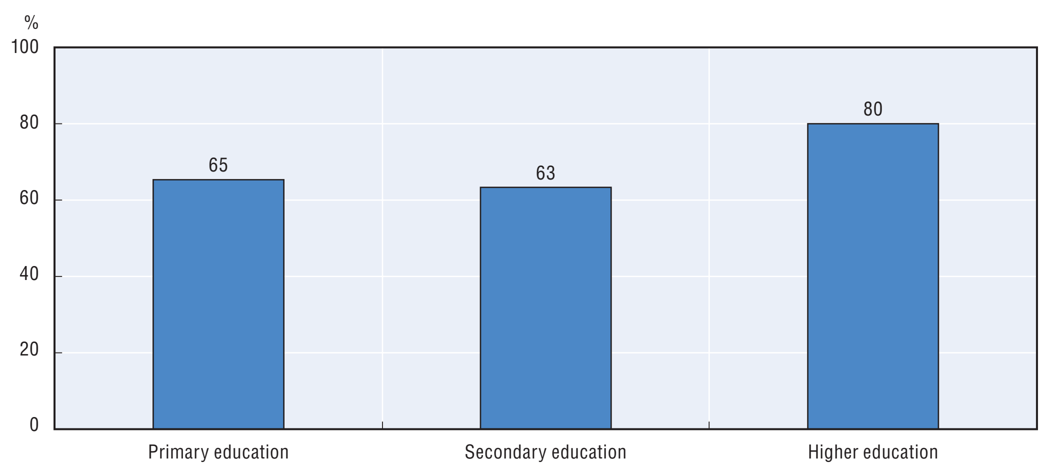
StatLink http://dx.doi.org/10.1787/888933283515

Finland, Italy, the Netherlands, Slovenia and the United Kingdom have the largest share of graduates who considered their workplace in the education sector to be highly innovative for at least one type of innovation. However, graduates in these countries differ in their perception of how innovative the education sector is compared with other sectors. In Finland, they considered the education sector to be about averagely innovative, whereas in the Netherlands, Slovenia and the United Kingdom, they consider the education sector to be more innovative than the average across all sectors of the economy, and in Italy they consider it less innovative. In contrast, the Czech Republic, France, Hungary and Portugal have the smallest shares of graduates who consider the education sector to be highly innovative for at least one type of innovation. Graduates working in the education sector in these four countries consider their own sector to be less innovative than graduates working in other sectors of the economy. In the Czech Republic and Portugal, the difference is particularly marked compared with other sectors (Figure 1.3).

The survey also analysed the education sector at different levels of education. Although no country-by-country analysis was possible, the survey found that 80% of graduates employed in tertiary education considered their workplace to be highly innovative, compared to 65% of graduates employed in primary education and 63% employed in secondary education (Figure 1.4).

Figure 1.4. **Education professionals working in highly innovative workplaces, by education level**

Percentage of graduates in workplaces they perceive to be highly innovative for at least one type of innovation, 2005 or 2008



Data are ranked by level of education.

Source: Figure 1.12 from OECD (2014), *Measuring Innovation in Education: A New Perspective*, Educational Research and Innovation, OECD Publishing. *http://dx.doi.org/10.1787/9789264215696-en.*

StatLink http://dx.doi.org/10.1787/888933283539

Further key findings of the analysis of these surveys were:

- Education is at or below the average in terms of the speed of adoption of innovation: 38% of graduates reported that their educational establishment was mostly at the forefront in adopting innovations, new knowledge or methods (against 41% on average in the economy).
- Higher education stands out in terms of speed of adopting innovation, above the economy average, and well above the rate in primary and secondary education.

- The education sector has significantly higher levels of innovation than the public administration on all indicators and is at least as innovative as the health sector on each measure.

Measuring organisational change in education

The second approach to measuring innovation uses micro-data collected within schools. *Measuring Innovation in Education* presents a range of indicators based on an approximation of the traditional innovation definition (OECD, 2014). It applies the working definition of innovation as the implementation of a new or significantly changed process, practice, organisational or marketing method observed at the education system level, concentrating particularly on changes in practice. However, given that we cannot directly observe whether any of these changes are an "improvement", it has had to depart from the Oslo Manual definition and use change as a proxy measure. It can be assumed that change occurs because of a belief that the new version is an improvement of some educational goal.

The project captured innovation as a significant change in some key practices in educational establishments by drawing on the PISA, TIMSS and PIRLS databases. Although these studies are designed to measure student outcomes, they also collect information about educational and teaching practices at a point in time. The repeated cross-sectional nature of the studies makes it possible to map trends over time. By analysing responses to questions that have been asked in at least two waves of the study, it is possible to identify changes in professional practices or in classroom or school resources (see Box 1.3 for an example).

This methodology raises a second question: how much does a variable need to change before it is considered an innovation, that is, a significant (or noteworthy) change? There is no definitive answer to this question, which requires, in any case, some subjective judgment. For example, the degree to which the adoption of a teaching practice by 10% more teachers can be considered innovative depends on the context: it may be considered more significant in a country where 10% of teachers used it than in a country where 70% of teachers already used it. *Measuring Innovation in Education* therefore uses summary tables of effect sizes to help readers make this judgment. Effect sizes give a standardised measure of these changes and help interpret the relative magnitude of the change: the greater the effect size, the higher the magnitude (and likely "significance") of change over time.

Measuring Innovation in Education analysed the effect sizes of changes between 2003 and 2011 in the TIMSS databases on various pedagogic and organisational variables. It concluded:

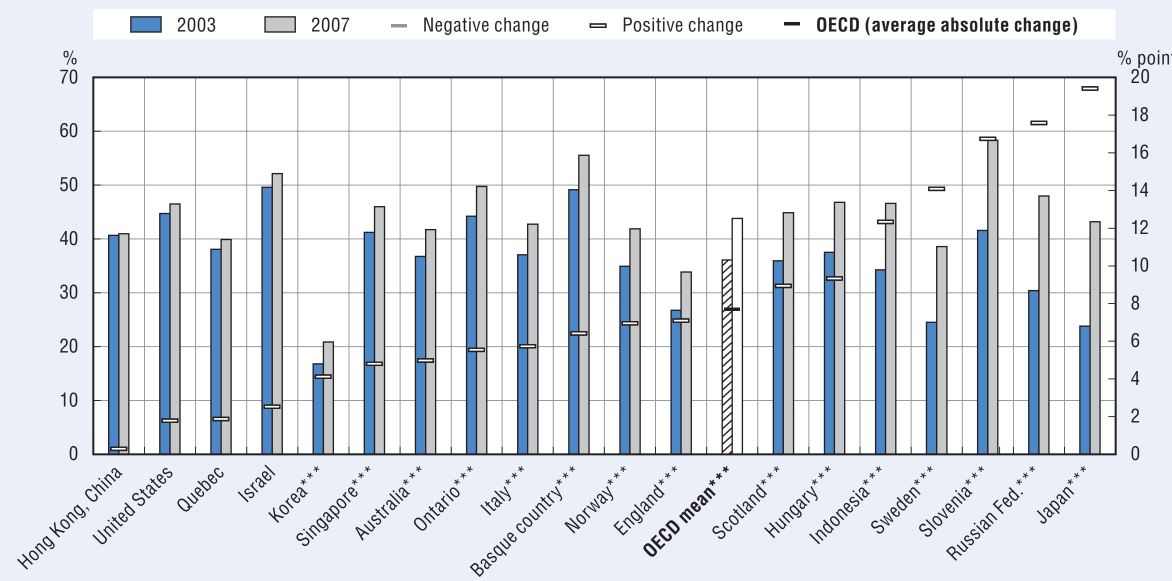
- There have been large increases in innovative pedagogic practices across all countries covered in areas such as relating lessons to real life, higher order skills, data and text interpretation, and personalisation of teaching.
- Teachers have innovated in their use of assessments and in the accessibility and use of support resources for instruction.
- Educational organisations have innovated in the areas of special education, the creation of professional learning communities for teachers, evaluation and analytics, and building relationships with external stakeholders, such as parents.
- In general, countries with greater levels of innovation have seen increases in certain educational outcomes, including higher (and improving) 8th grade mathematics performance, more equitable learning outcomes for students of all abilities and more satisfied teachers.

- Innovative educational systems generally have higher levels of expenditure than non-innovative systems but their students are no more satisfied than those in less innovative systems.
- Overall, there has been more innovation in classroom practices than school practices between 2000 and 2011 (OECD, 2014a).

Box 1.3. **Example of innovation in instructional practices**

Relating 8th grade maths learning to students' daily life, according to students

Percentage of students whose teachers ask them to relate what they learn in class to their daily life in at least half their lessons and change over time



*** = change significant at the 0.01 level; ** = change significant at the 0.05 level; * = change significant at 0.1 level

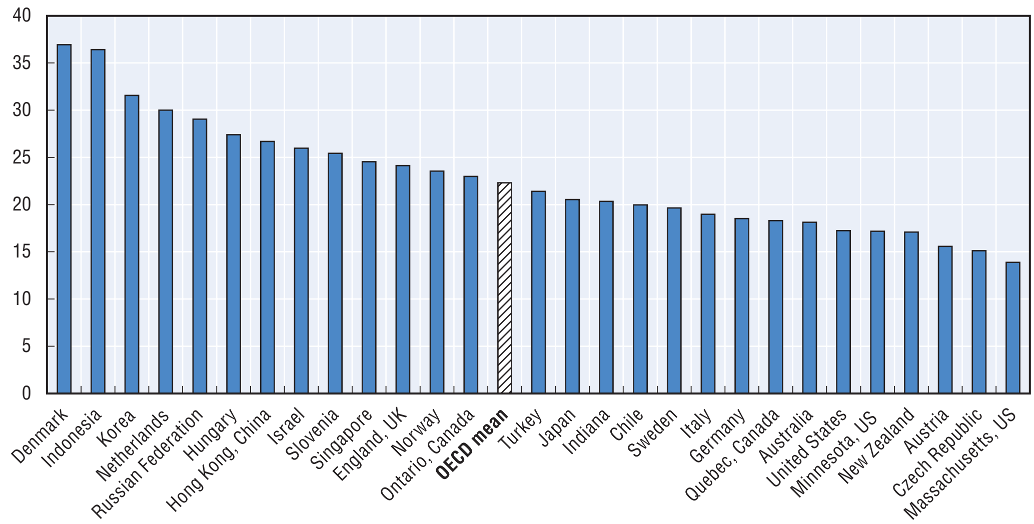
Source: Authors' calculations based on TIMSS (2003 and 2007). OECD, (2014) *Measuring innovation in education: A New Perspective, Educational Research and Innovation, OECD Publishing. http://dx.doi.org/10.1787/9789264215696-en.*

StatLink http://dx.doi.org/10.1787/888933083202

One innovation in instructional practices could involve changes in the extent to which students apply their knowledge and skills to their real lives or to activities such as interpreting of data or reasoning. The aim of such innovation may be to encourage engagement and motivation by making lessons more relevant or to encourage students' critical thinking skills. In maths, on average, the share of students in OECD countries reporting that they related what they learned to their daily lives rose by 8 percentage points between 2003 and 2007.

All the practices can be combined together into a composite innovation index to measure overall change in pedagogical and organisational practices in schools between 2000 and 2011 (Figure 1.5). Based on this index, the countries showing the most innovation at the classroom and school levels in primary and secondary education are Denmark (37 points), Indonesia (36 points), Korea (32 points) and the Netherlands (30 points). The countries showing the least innovation are the Czech Republic (15 points), Austria (16 points), and New Zealand and the United States (both 17 points). The OECD average is 22 points, where points can be read as an average effect size multiplied by 100.

Figure 1.5. **Overall composite education innovation index, 2000-11**



Source: Figure 17.1 from OECD (2014), *Measuring Innovation in Education: A New Perspective*, Educational Research and Innovation, OECD Publishing. *http://dx.doi.org/10.1787/9789264215696-en.*

StatLink http://dx.doi.org/10.1787/888933086546

This analysis demonstrates that education is not an innovation-aversive sector, and that changes leading to improvement are taking place. So, the potential for innovation in education is real.

The education and skills dimension of innovation

The argument in favour of innovation in education is often made in the broader context of the contribution of education and skills to successful innovation. Indeed, successful innovation in economies and societies rests on a good foundation of education and skills. If education systems fail to fulfil this role, they need innovation themselves.

Skills for innovation

Education policies to foster innovation have traditionally focused on increasing participation in science, technology, engineering, and mathematics (STEM) disciplines. Recently, however, a more comprehensive view of innovation has emerged which recognises the contribution of a wider set of skills and disciplines. While STEM specialists are undoubtedly important for certain types of innovation, particularly technological innovation, government policy needs to take a broad view of the competencies used in the innovation process (Box 1.4).

Surveys of tertiary-educated employees show that innovation requires a broad range of skills. The international REFLEX survey, which interviews graduates five years after their graduation, shows that innovative employees (defines as those working in an organisation that innovates and participating in the introduction of these innovations) report using more of all types of skills in their jobs than their non-innovative counterparts. Among the self-reported use of skills that most distinguish innovative from non-innovative workers are "coming up with new ideas and solutions" (creativity), "a willingness to question ideas" (critical thinking), and "the ability to present new ideas or products to an audience" (communication) (Figure 1.6).

Box 1.4. **How human capital shapes innovation**

Skilled people generate knowledge that can be used to create and implement innovations.

Having more skills raises the capacity to absorb innovations.

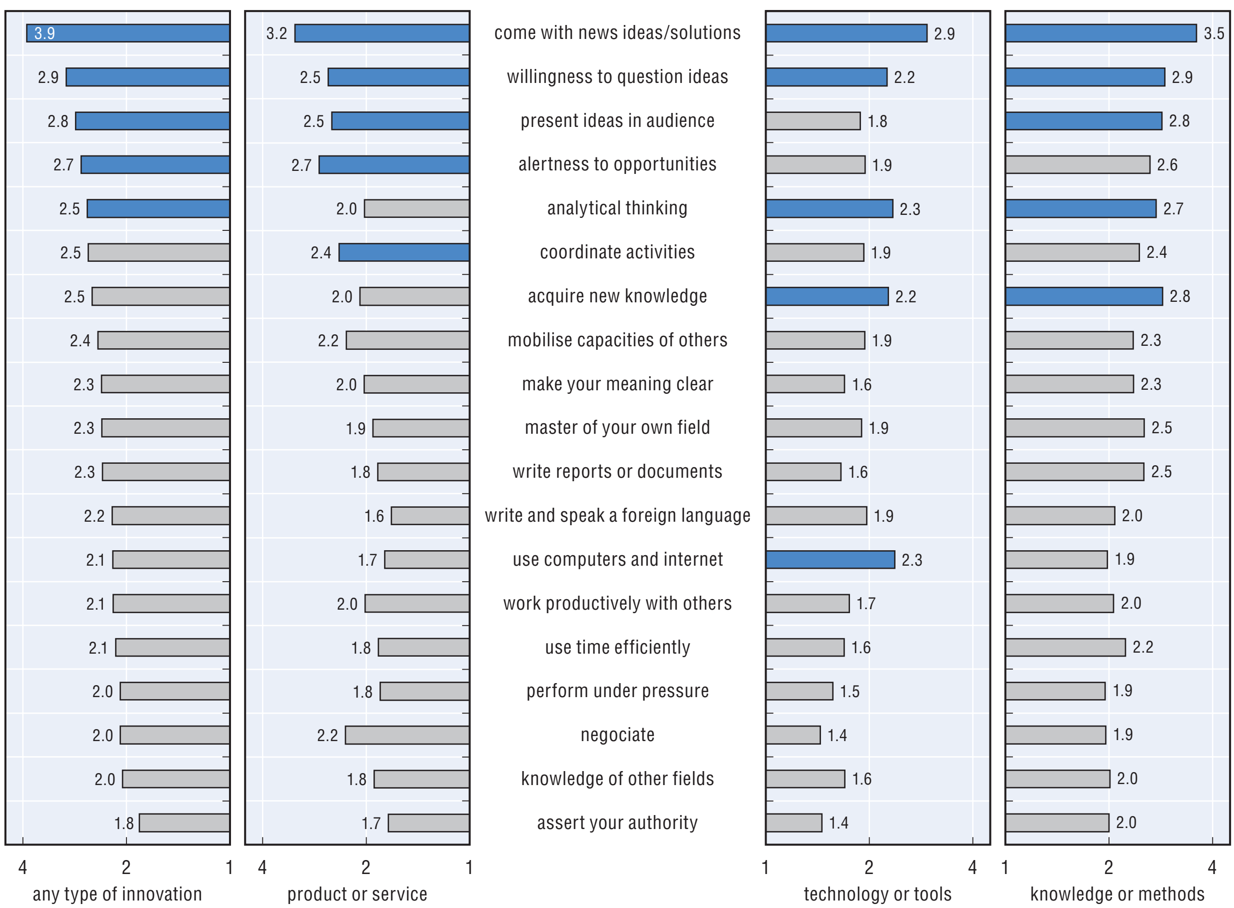
Skills interact synergistically with other inputs to the innovation process, including capital investment.

Skills enable entrepreneurship. Entrepreneurship is often a carrier of innovation and structural change. Skills and experience are crucial to enterprise growth and survival.

Skilled users and consumers of products and services often provide suppliers with valuable ideas for improvement.

Source: OECD (2015a), *The Innovation Imperative: Contributing to Productivity, Growth and Well-Being*, *http://dx.doi.org/10.1787/9789264239814-en*.

Figure 1.6. **Critical skills for the most innovative jobs**



Note: Based on Reflex and Hegesco dataset. Odds ratio for the likelihood of mentioning the skill as required for workers in innovative jobs, compared to workers in non-innovative jobs, are presented. Generalised odds ratio are computed from logistic regressions controlling for country and sector of activity. The five most critical skills are highlighted in blue for each type of innovation.

Source: Avvisati, F., G. Jacotin and S. Vincent-Lancrin (2013), "Educating higher education students for innovative economies: What international data tell us", *Tuning Journal for Higher Education*, Vol. 1/1, pp. 223-240.

Reflecting this evidence from innovative workers, skills for innovation can be grouped into three broad categories:

- Subject-based skills, which represent knowledge and knowhow in a particular field.
- Thinking and creativity, including both higher-order skills and creative cognitive habits. These competencies include critical faculties, imagination and curiosity.
- Behavioural and social skills, including skills such as self-confidence, leadership and management, collaboration and persuasion.

These insights help define the role of education in innovation. Developing excellent subject-based knowledge is undoubtedly important for an innovative society, but it is not enough on its own. In addition to raising academic achievement across all levels of education, innovation policies need to pay more attention to which skills young people acquire. Fostering critical thinking, creativity, and behavioural and social skills should be viewed as a central element of the remit of schools, colleges and universities (Box 1.5).

Box 1.5. **Fostering and assessing creative and critical thinking skills**

While creative and critical thinking skills are critical innovation and usually considered part of the "21st century skills", teachers, students and policy makers still don't have a good representation of what they mean in formal education. How can they be taught and learnt, and how do we know whether students have acquired them?

The OECD Centre for Educational Research and Innovation (CERI) works with schools, higher education institutions, and experts within 14 OECD countries to develop a common, teacher-friendly language about creativity and critical thinking. The work thus aims to improve the quality of learning and teaching within participating countries and to showcase how education could enhance students' well-being and employability in innovative societies, with a balanced attention to students' technical, creative, critical but also social and behavioural skills.

A bank of educational resources. One output of the project will be a bank of pedagogical resources including an international rubric, a set of pedagogical activities and lesson plans, and examples of student work showcasing how students demonstrate creative and critical thinking skills at different ages and in different domains. The internationally developed rubric will articulate explicit developmental and progression standards for specific levels of schooling and/or higher education in creative and critical thinking skills. This will help teachers and students to develop these habits of minds and assess their progress formatively by better understanding what to look for.

Evidence-based innovation. The project will also measure the effects of the intervention on creativity, technical skills as well as on behavioural and social skills. It will identify some factors for the successful development of these skills in formal education. With its robust quasi-experimental research design, it promotes the rigorous monitoring of innovative practices so they can be enhanced, adjusted to and scaled up to different contexts.

See: "Innovation strategy for education and training", OECD website, *www.oecd.org/edu/innovation*.

By influencing what and how children learn, school curricula play a central role in developing skills from an early age. The role of skills for innovation in national curricula appears to have become more prominent in recent years in many countries. A survey of OECD countries in 2009 found that all responding countries included at least some aspects of 21st century skills in primary and lower-secondary curricula (Anandiadou and Claro, 2009). Most primary and secondary education curricula in developed countries refer to critical thinking, creativity, problem solving and social skills.

Even in many Asian economies, where education systems have typically been associated with traditional learning models and a narrow focus on STEM subjects, there are signs of new efforts to emphasise creativity and critical thinking in national curricula. Since 2009, the Republic of Korea expects its schools to foster creativity as part of subject-based learning, but also to devote almost 10% of overall school time to projects and other transversal activities that foster creativity. By the end of secondary school, students in Singapore are expected to have developed critical and inventive thinking skills as well as social and emotional abilities such as being "resilient in the face of adversity". Singapore has also adopted a mathematics curriculum based around metacognitive approaches to complex problem solving. In the People's Republic of China, since 2009, more emphasis has been placed on changing traditional teaching models. In Indonesia, the practice of "lesson study" aims to promote professional learning among teachers and help them to reflect on their teaching methods and align those methods with the needs of students.

In many other countries across the world, education systems start from different positions and face different challenges in curriculum reforms. In India, for example, the rote learning system (using repetition as a technique for memorisation) still prevails in many Indian schools, impeding the development of curricula focused on skills for innovation. But encouraging examples of curriculum reform and organisational innovation have started to appear in India — the Apeejay school network, for example, promotes educational programmes for creativity and innovation, with practices such as enquiry-based projects designed to develop creativity and original thinking. Not all efforts need to take place in the classroom, however. In Costa Rica, for example, the Innovating at Home programme aims to teach parents how to develop their children's creativity from an early age. These examples show there is increasing emphasis and interest in developing wider skills in a variety of country contexts.

Entrepreneurship education

There are close conceptual links between innovation-specific skills and entrepreneurship skills (OECD, 2014b). Moreover, entrepreneurship is a critical vehicle for the introduction of innovation. During the past decade, most OECD countries have started to promote entrepreneurship skills at all levels of education (Hytti and O'Gorman, 2004). Entrepreneurship education is a popular policy tool to develop entrepreneurial skills and encourage a more favourable culture and attitude towards innovation and the creation of new firms.

School-level entrepreneurship education often involves trying to foster entrepreneurial skills through problem-solving activities and contextual learning based on interactive projects and games. By contrast, entrepreneurship education for upper secondary school students and young adults is more typically based on providing information and developing the practical knowledge and skills needed to run a business.

For example, the INJAZ Junior Achievement programme in the Middle East aims to provide business skills and financial literacy to students in Egypt, Jordan, Lebanon, Morocco, Saudi Arabia and the United Arab Emirates through a mixture of classroom and extracurricular activities.

Different country efforts take many forms. Denmark's 2012 National Innovation Strategy, for instance, promotes the integration of innovation and entrepreneurship into the mainstream curriculum and increases practice-based teaching in schools and innovation courses in teacher training programmes. In addition, some countries — including Finland, Portugal and Sweden — have embedded entrepreneurship education into primary and secondary school curricula, while a number of OECD countries, including Australia and Ireland, encourage the integration of information and communication technologies into schools.

Evidence for the effectiveness of school-level entrepreneurship education programmes is mixed. Oosterbeek et al. (2010) showed that a "mini-company" initiative in the Netherlands had no statistically significant effect on the entrepreneurial skills of students and a significant negative effect on their willingness to start a business. But other studies suggest that entrepreneurship education in school can develop non-cognitive entrepreneurial skills (including persistence, creativity and proactivity), at least in the short term. More work is needed to draw general conclusions and determine the successful elements of this type of intervention.

A rapidly growing number of higher education institutions worldwide are providing entrepreneurship support for their students, graduates, researchers and professors. Entrepreneurship support in higher education generally has two strands. The first strand aims at developing entrepreneurial mindsets. It stresses the development of such traits as self efficacy, creativity, risk awareness, building and managing relationships. The second strand aims to build the attitudes, skills and knowledge needed to successfully launch and grow a new business.

In recent years, the frequent use of business plans to teach entrepreneurship courses has been complemented by greater involvement of entrepreneurs in the teaching process, as well as an increasing use of social media and massive open online courses. It is increasingly common to find classrooms in which students are challenged to identify and use a wider range of knowledge sources to find novel solutions.

Today, more than ever, schools and universities are expected to respond to the social and economic needs of society, such as facilitating graduate employability, contributing to economic growth and local development, assisting innovation, and stimulating the birth of new enterprises. In this connection, HEInnovate (*www.heinnovate.eu*) – a joint initiative of the OECD and the European Commission – is a tool to help higher education institutions identify and act on opportunities for capacity development, including in teaching and research to enhance innovation and entrepreneurship (Box 1.6).

Entrepreneurship education also faces a gender challenge. The OECD (2012) has found that across OECD countries there are more male than female entrepreneurs, and the share of women who choose to run a business has not increased substantially in most countries. If women's intentions to engage in entrepreneurship are constrained by gender-specific conditions, society and the economy will fail to maximise their entrepreneurial potential. Currently, more women than men become business owners out of necessity. On average, female-owned businesses register lower profits and labour productivity than male-owned businesses. These disparities can mostly be explained by differences in the size and capital intensity of female- and male-owned firms. Female entrepreneurs rely substantially less than men on external loans, but it is not clear if this is because women are less inclined to use external finance or because women experience discriminatory treatment in capital markets (or both). Female-owned firms also differ from male-owned firms in terms of innovation outcomes but the lower levels of product and process innovation in enterprises founded by women can be explained by the sector, investment levels and sizes of their firms, as well as by their founders' entrepreneurial experience prior to starting up.

Ensuring that women have equal opportunities to contribute to innovation also means making the most of the available talent pool. Analysis of "gendered innovation" shows that removing gender biases can improve research and innovation and open up new market opportunities (European Commission, 2013). As the European Commission noted:

"In engineering, for example, assuming a male default can produce errors in machine translation. In basic research, failing to use appropriate samples of male and female cells, tissues, and animals yields faulty results. In medicine, not recognising osteoporosis as a male disease delays diagnosis and treatment in men. In city planning, not collecting data on caregiving work leads to inefficient transportation systems." (European Commission, 2013)

Taking better account of gender differences is therefore of great importance for science and innovation.

Box 1.6. **Eembedding entrepreneurship into the curriculum learning in higher education**

The University of Twente (UT) is located in Enschede, a town with approximately 170 000 inhabitants in the eastern Netherlands. Established in 1961, with the aim of enhancing and reviving the regional economy after a major collapse of the regional textile industry, UT's main goal from the start has been to engage in research that is useful for society. All UT students should acquire entrepreneurship competencies by the end of their studies. Its educational model emphasises project-based and active learning, with a core emphasis on challenging students to identify and use many sources of knowledge to find novel solutions.

A new interdisciplinary programme – the Academy of Technology and Liberal Arts & Sciences (ATLAS) – was recently launched for students who want to combine social and technical perspectives in engineering studies. During the three-year programme, students make use of the latest technologies in areas such as nano-robotics, tracers for personal safety, 3D printing and renewable energy. The curriculum includes a "personal pursuit" element in which students focus on their personal interests in music, sports or a second language.

Founded in 1971, the Munich University of Applied Sciences is the second-largest university of applied sciences in Germany. In 2011 a new course format was developed, drawing together entrepreneurship education, knowledge exchange and start-up support. REAL (Responsibility, Entrepreneurship, Action- and Leadership-Based) projects involve teams of five to six students in a one-semester project. Each REAL project course has multiple teams working on different aspects or solutions of a central innovation challenge. The course is team-taught, by a professor and an expert on entrepreneurship. Professors and students work together to define the specific challenge. One of the first REAL project courses, on urban farming, involved four faculties (mechanotronics, architecture, design and business administration). Students developed ideas related to crop production, food processing, transportation and logistics. Linking REAL project courses to topics of global relevance (e.g. sustainability, mobility, energy and space) has proved successful for attracting external partners.

Source: OECD HEInnovate case studies, available at *www.heinnovate.eu*.

Innovation strategies in education

National innovation strategies for the education sector

Some countries have recognised that they need specific policies and implementation strategies to improve the contribution of education to their national innovation strategies and to innovate education systems themselves, and have started to develop specific national innovation strategies for the education sector. National education sector innovation strategies integrate specific strategies for research, development, targeted innovation and knowledge management in the education system. An excellent example is the Hungarian National Education Sector Innovation System (NESIS) (Box 1.7).

Box 1.7. **The Hungarian National Education Sector Innovation System (NESIS)**

In 2011 Hungary started developing its own national innovation strategy for the education sector. The NESIS is a sector-specific subsystem of the National Innovation System, representing the institutional framework of creating, sharing and using new knowledge with a view to improving education. The components of the NESIS are: theoretical and applied research aiming to improve education, development focusing on practice, innovation carried out within the education system and knowledge management. This framework is intended to provide opportunities for the specific actors in the NESIS to interact with each other as part of their work and for developing the standards and institutions which are also part of the system

Objectives and priorities of the NESIS Strategy

General aim: Innovative knowledge economy and society

Strategic goal: Effective teaching , successful learning

Specific objective: Well-functioning National Education Sector Innovation System (NESIS)

Fields of intervention

Developing regulatory, institutional and organisational frameworks
- Involving stakeholders
- Reviewing sector specific regulations from the perspective of innovation
- Drawing a map of organisations
- Strengthening links between research, practice and policy
- Supporting networks and communities of practice
- Developing a financing model adapted to objectives and priorities

Improving human conditions
- Exploring the human resources which may help innovation
- Strengthening R&D professionals
- Developing career models and competence standards
- Training wider group of participants in the framework of the initial and in-service training of teachers
- Strengthening leadership, organisation and organisational development

Ensuring quality
- Strengthening quality management and assessment functions
- Linking quality and innovation in sector level policy making
- Defining quality in the light of practical needs
- Exploiting the potential of international co-operation in the field of quality

Improving knowledge management
- Activating communication and co-operation among the participants of the knowledge triangle
- Closing knowledge gaps
- National and international co-operation of research and development capacities
- Supporting the exchange and dissemination of knowledge
- Sharing good practices
- Renewing the initial and in-service training of teachers

Exploiting the potential of technological development
- Making new educational technologies accessible
- Providing support through funding arrangements
- Removing and replacing obsolete technologies
- Incentivising the use of new applications
- Introducing an assessment and accreditation system for new technologies
- Creating an environment which supports the development of competencies needed for the application of new technologies
- Innovation focussed ICT strategy for education

Implementation
- Building upon existing components
- Combining top-down and bottom-up approaches
- Relying on synergies arising from the application of multiple tools
- Taking into account the specifics of different levels of educational policy making
- Taking into account the expected contributions and expectations of stakeholder groups
- Giving key attention to timeframes
- Focusing on horizontal objectives
- Ensuring coherence and exploiting synergies arising from links
- Thinking in complex systems and ecosystems
- Interpreting implementation as a learning process which enables continuous adjustments

Box 1.7. **The Hungarian National Education Sector Innovation System (NESIS)** *(cont.)*

An international review (Schuller, 2010) of the NESIS concluded its relevance for the international community was as follows:

It is possible to identify a sectoral innovation system in the education sector, and to analyse and to assess its performance.

A well-developed sectoral innovation system contributes significantly to the performance of the education system and to the achievement of key public policy goals in the education sector.

There is a need for a coherent government strategy to develop the sectoral innovation system of education.

Applying the most recent approaches of innovation research and innovation policy thinking to the education sector can help such a strategy emerge.

The development of an education sectoral innovation strategy is a good framework to bring together the key partners interested in improving the quality of education.

Source: Institute for Educational Research and Innovation (2011), *Strategy proposal for the development of the Hungarian national education sector innovation system*, *http://ofi.hu/sites/default/files/ofipast/2011/05/8.1.-Vezetoi_osszefoglalo-EN.pdf*.

General innovation strategy frameworks for education

Over the past decades, recognising the urgent need for innovation in education, several initiatives have tried to develop general frameworks, principles and guidelines for innovation strategies in education.

For example, the European Union has recognised the importance of specific education and skills oriented innovation strategies as a fundamental component of general innovation strategies. The 2009 Manifesto for the EU Year of Creativity and Innovation (Box 1.8) includes a specific section on the strategies needed in education.

Box 1.8. **Manifesto of the European Year of Creativity and Innovation, 2009**

Schools and universities need to be reinvented in partnership with teachers and students so that education prepares people for the learning society. Retrain teachers and engage parents so that they can contribute to an education system that develops the necessary knowledge, skills and attitudes for intercultural dialogue, critical thinking, problem-solving and creative projects. Give a strong emphasis to design in education at different levels. Establish a major European-wide research and development effort on education to improve quality and creativity at all levels.

1. Nurture creativity in a lifelong learning process where theory and practice go hand in hand.
2. Make schools and universities places where students and teachers engage in creative thinking and learning by doing.
3. Transform workplaces into learning sites.
4. Promote a strong, independent and diverse cultural sector that can sustain intercultural dialogue.
5. Promote scientific research to understand the world, improve people's lives and stimulate innovation.
6. Promote design processes, thinking and tools, understanding the needs, emotions, aspirations and abilities of users.
7. Support business innovation that contributes to prosperity and sustainability.

Source: European Ambassadors for Creativity and Innovation (2009), *Manifesto*, European Union, *www.create2009.europa.eu/fileadmin/Content/Downloads/PDF/Manifesto/manifesto.en.pdf*.

Another example is a recent study concluding the OECD/CERI Innovative Learning Environments project which investigated the forms, principles, conditions and policies for the "redesign" of schooling at a micro, meso and meta-level. This framework, based on an extensive study of innovative cases and systems, can also be seen as a comprehensive education-sector innovation strategy (Box 1.9).

Box 1.9. **Conditions for education system redesign in the OECD/CERI ILE Innovative Learning Environments project**

1. reducing standardisation, fostering innovation, broadening institutions
2. appropriate accountability and metrics for 21st century learning
3. promoting learning leadership, trust and learner agency
4. widespread collaborative expert professionalism
5. ubiquitous professional learning
6. connectivity and extensive digital infrastructure
7. flourishing cultures of networking and partnership
8. powerful knowledge systems and cultures of evaluation.

Source: OECD (2015c), *Schooling Redesigned: Towards Innovative Learning Systems*, *http://dx.doi.org/10.1787/9789264245914-en*.

In addition, the World Economic Forum's Global Agenda Council on Education recent white paper *Unleashing Greatness. Nine Plays to Spark Innovation in Education*, offers a series of "plays" on how to achieve holistic system reform in education (Box 1.10).

Box 1.10. **World Economic Forum: Nine "plays" to spark innovation in education**

- **Provide a compelling vision of the future**: Educational leaders need to present a persuasive vision of how the future can be better. Systems stay stable because they serve some stakeholders well, but often not students. Leaders need to demonstrate that the current situation cannot endure and provide an alternate vision of the system's purpose be and who it should serve. A compelling vision can align internal and external stakeholders around the need for change. It can also stimulate public demand for a more effective education system that meets the needs of all.
- **Set ambitious goals that force innovation**: Setting ambitious goals, particularly nearly impossible ones, forces the entire system to innovate and drive toward those goals. Ambitious goals should be paired with enough flexibility to create room for new innovation. Compelling goals can align internal and external stakeholders around the importance of change, stimulate public demand for innovation and dramatically accelerate system progress.
- **Create choice and competition**: Choice and competition can create pressure for schools to perform better. Choice can be created at many levels – students and parents can choose schools, or educators can have greater choice in where to work. Better choice, however, depends on the availability of quality options and quality information on those options. Creating options can improve outcomes, but, when dealing with markets, special care should be taken to ensure that equity is not sacrificed for the sake of efficiency.
- **Pick many winners**: When launching competitions, or new service models, pick more than one winner. Supporting multiple ideas or approaches at once spurs all providers to continue to improve and compete – whether you are testing new technology tools or new school models. Systems that reward a single "winner" discourage further improvement and learning, and tend toward stagnation. As seen with challenge prizes, the goal should be to use funding or recognition to stimulate a wave of innovation, generating new ideas, patents and market participation.

Box 1.10. **World Economic Forum: Nine "plays" to spark innovation in education** *(cont.)*

- **Benchmark and track progress**: High-quality data at the school and district level allows leaders – and everyone – to see progress towards the goals. It can also be used by leaders as a discussion point with principals and staff to identify and troubleshoot problems. No matter the quality and clarity of the data, the data only provides an imperfect representation of something even more important: the real world learning outcomes that matter to citizens.
- **Evaluate and share the performance of new innovation**: Innovations need to actually work. For education systems to encourage quality, there needs to be transparent information on how effective new innovations and technologies are – do they work, over what time period, and based on what criteria? Schools and education systems should invest in quality performance and impact evaluations of new innovations and broadly share the results.
- **Combine greater accountability and autonomy**: Devolving authority to the school level can remove barriers to innovation and allow school leaders the flexibility to explore new approaches. Increased autonomy needs to be paired with increased accountability, in which school leaders are accountable for the choices and results they deliver. This accountability requires greater transparency and clear performance metrics. Schools need both data and feedback, ministries need to assess the effectiveness of new approaches, and the general public deserves accurate information on school performance.
- **Invest in and empower agents of change**: New agents of change require support to make their ideas real and effective at scale. System leaders need to provide leadership development, coaching and mentorship and other support systems enabling innovators to succeed. These innovators can be both inside or outside the system; teachers and administrators may be sources of innovation inside while new charter school/ academy operators or social entrepreneurs may operate outside the system. Talent development needs to be carefully coordinated with policy, programmes and local communities' needs.
- **Reward successes (and productive failure)**: Public and private recognition makes it easier for existing innovators to take risks and encourage the emergence of new actors. Rewards also highlight models of success, giving them greater exposure and increasing the likelihood of expansion. System leaders should reward both successful models and ambitious failures that support their goals and vision.

Source: World Economic Forum (2016), *Unleashing Greatness. Nine Plays to Spark Innovation in Education*, *www3.weforum.org/docs/WEF_WP_GAC_Education_Unleashing_Greatness.pdf*

Key messages for innovation policies in education

As a system, education would benefit from having a well-designed innovation strategy. Contrary to common belief, education is not innovation averse: the amount of change in education is comparable to similar public sectors, and education professionals consider their workplaces to be as innovative as the economy at large. Despite this, education has not managed to harness technology to raise productivity, improve efficiency, increase quality and foster equity in the way other public sectors have. Innovation policies in education have often focused on fragmented issues or on the wrong goals, sometimes driven by a concern for quick wins, but without sustainable gains in the long run. Well-designed innovation strategies in education could leverage the potential of new technology and, with the right kind of policy mix, can contribute to both more efficiency and better outcomes for quality and equity.

- Improved measurement must be the foundation of innovation in education. Based on a solid definition of "improvement" at different levels in the system, regular data collection should assess changes over time in improved pedagogical and organisational practices.

- Education needs a strong and efficient system of knowledge creation and diffusion, extending from scientific research into teaching and learning, to the more applied bodies of knowledge in the teaching profession and knowledge entities in the system.
- While innovation in education is not synonymous with the introduction of digital technology, innovation strategies should include the smart implementation and use of technology in a way that leverages their potential for better teaching and learning practices. This will be dealt with in subsequent chapters of this book.
- Effective innovation strategies in education must include an appropriate governance model: identifying key agents of change and champions, defining the roles of stakeholders, tackling pockets of resistance, and conceiving effective approaches for scaling and disseminating innovations.
- Finally, innovation in education requires strong evaluation. Without a broad and widely shared culture of evaluation, innovation in education will remain stuck at the level of well-intended but isolated pioneering efforts. Finding out what really works, what doesn't and why is key to developing a body of knowledge that can guide future innovations.

Besides being a field of innovation in its own right, education has also a key relationship to innovation at large: as a system developing the skills for innovation in economies and societies. Recent accounts of innovation and innovation strategies have emphasised the importance of the skills needed to start, disseminate and implement innovation. Critical thinking, creativity and imagination, on top of strong subject-based, and social and emotional skills, are key to the success of innovation. Education policies need to cover developing these skills as a matter of key importance. Entrepreneurship education is a good example of a setting in which such skills can be fostered and nurtured.

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Innovating Education and Educating for Innovation
The Power of Digital Technologies and Skills

Chapter 2

Digitalisation, digital practices and digital skills

As technological change continues to accelerate, the digital economy is rapidly permeating the whole of the world economy, making digital skills key for almost everyone. This chapter briefly surveys the use of the Internet and information and communications technology by businesses and individuals and the links between digital behaviour and age, education and socio-economic background. It considers how far the "digital divide" is closing for students from different countries and backgrounds.

Using data from international surveys, the chapter looks at digital skills among the adult population, and the impact they have on employment and wage levels, and national policies to foster greater skills. Finally, it examines digital skills among 15-year-olds and whether the gap between those from the richest and poorest households is closing as Internet access becomes more widespread.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Digitalisation

The digital economy continues to gain ground

The digital economy is growing quickly (OECD, 2015). It permeates the world economy from retail (e-commerce) to transportation (automated vehicles), health (electronic records and personalised medicine), social interactions and personal relationships (social networks) and also education. Information and communications technology (ICT) is integral to peoples' professional and personal lives; individuals, businesses and governments are increasingly interconnected via a host of devices at home and at work, in public spaces and on the move. These exchanges are routed through millions of individual networks ranging from residential consumer networks to networks that span the globe. The convergence of fixed, mobile and broadcast networks, combined with the use of machine-to-machine communication, the cloud, data analytics, sensors, actuators and people, is paving the way for machine learning, remote control, and autonomous machines and systems. Devices and objects are becoming increasingly connected to the Internet of Things, leading to convergence between ICT and the economy on a grand scale.

At the same time, the growing number of computer-mediated transactions and the accelerating migration of social and economic activities to the Internet are contributing to the generation of a huge volume of (digital) data commonly referred to as "big data". Big data are now used by organisations, often in highly creative ways, to generate innovations in products, processes, organisational methods and markets. Big data could enable vast technological and non-technological innovation. The declining cost of data collection, storage and analytics, combined with the increasing deployment of smart ICT applications, generates large amounts of data, which can become a major resource for innovation and efficiency gains, as long as privacy issues can be addressed. The benefits may also include enhanced data-driven research and development (R&D). For example, the deployment of second-generation genome sequencing techniques with embedded data-mining algorithms resulted in the cost of each human-like genome sequence dropping from USD 1 million to USD 1 000 in just five years (2009-14).

However, the use of big data creates several issues for governments. Governments will need to foster investments in broadband, smart infrastructure and the Internet of Things as well as in data and analytics, with a strong focus on small and medium-sized enterprises (SMEs) and high value-added services. It will also be important to promote skills and competences in analysing data. Moreover, removing unnecessary barriers to the development of the Internet of Things, such as sector-specific regulations, could help ensure its impact across the economy.

An open and accessible Internet, with high fixed and mobile bandwidth, is essential for innovation in the 21st century. The Internet has become a platform for innovation thanks to its end-to-end connectivity and lack of gatekeepers, providing a place where creativity, the exchange of ideas, entrepreneurship and experimentation can flourish. Furthermore, an open Internet enables the management of global value chains, as companies increasingly spread production across borders.

However, governments need to strike the right balance between the social benefits of openness and private preferences for a less open system. It will be particularly important to preserve the open Internet and promote the free flow of data across the global ecosystem while also addressing individuals' concerns about privacy violations and promoting a culture of digital risk management across society. Finally, to ensure the digital economy is inclusive, governments need to assess market concentration and address barriers to competition. Box 2.1 outlines the key areas national digital economy strategies will have to address.

Box 2.1. **Key pillars of national digital economy strategies**

- Further develop telecommunications infrastructure (e.g. access to broadband and telecommunication services) and preserve the open Internet.
- Promote the ICT sector including its internationalisation.
- Strengthen e-government services including enhanced access to public sector information (PSI) and data (i.e. open government data).
- Strengthen trust (digital identities, privacy and security).
- Encourage the adoption of ICTs by businesses and SMEs in particular, with a focus on key sectors such as healthcare, transportation and education.
- Advance e-inclusion with a focus on the aging population and disadvantaged social groups.
- Promote ICT-related skills and competences including basic ICT skills and ICT specialist skills.
- Tackle global challenges such as Internet governance, climate change and development co-operation.

Source: OECD (2015a), *OECD Digital Economy Outlook*, *http://dx.doi.org/10.1787/9789264232440-en*, p. 22.

There are plenty of indicators illustrating the digitalisation of economies and societies. The number of Internet users in OECD countries increased from less than 60% of adults in 2005 to about 80% in 2013, reaching 95% among young people, although with large differences across and within countries. Fifteen-year-olds in the OECD spend about three hours on the Internet on a typical weekday, and more than 70% use the Internet at school. In OECD countries, 62% of Internet users participate in social networks and 35% use e-government services. About half of individuals in OECD countries purchase goods and services on line, and almost 20% in Denmark, Korea, Sweden and the United Kingdom use a mobile device to do so.

Almost no business today is run without the help of ICT. In 2014, almost 95% of enterprises in the OECD area had a broadband connection and 76% had a website or home page and 21% sold their products electronically. Over 80% of enterprises used e-government services. However, only 21% conducted sales on line and only 22% used cloud computing services. Overall, there are still large differences across countries in the use of ICT tools and activities within enterprises, suggesting there is much scope for further uptake and use of ICT. These differences are is closely, but not exclusively, related to differences in countries' share of smaller firms.

Higher-speed Internet, lower unit prices and smart devices have favoured new and more data-intensive applications. Wireless broadband subscriptions in the OECD area increased over twofold in just four years: by June 2014, more than three out of four individuals in the OECD area had a mobile wireless broadband subscription. Mobile broadband is also widely available in many emerging and less developed countries (OECD, 2013a). In sub-Saharan Africa, for example, subscriptions grew from 14 million in 2010 to 117 million in 2013.

In less than two years, the number of pages viewed from mobile devices and tablets is estimated to have risen from 15% to over 30% of total. In 2013, over 75% of active Facebook users connected via a mobile device. International differences in speed and prices remain significant, however, even among OECD countries. In December 2013, the share of subscribers to high-speed broadband – offering speeds over 10 megabits per second (Mbit/s) – ranged from over 70% to under 2% across OECD countries. Depending on country, smartphone users in the OECD may pay up to seven times more for a comparable basket of mobile services.

ICT-producing industries, together with publishing, digital media and content industries, accounted for about one-quarter of total OECD BERD in 2011. In 2014, patents in ICT-related technologies accounted for one-third of all applications to main patent offices. In the last ten years, the share of data mining in total patents more than tripled, and the share of machine-to-machine communication patents increased sixfold.

Many emerging technologies rely on innovations in ICT. In OECD countries, about 25% of ICT patents also belong to non-ICT areas. As a result of ICT, access to inventions and innovations is faster, cheaper and better, with technology now a part of mass culture. Widespread adoption of broadband has opened up a world of digital content to users. Cloud computing has shown great potential as a platform for new services. It has significantly reduced ICT barriers for SMEs, allowing them to expand faster and innovate.

Box 2.2. **Seizing the benefits of digitalisation for growth and well-being: New horizontal OECD work**

As the diffusion and use of digital technologies increases, the cost of data collection, storage and processing continues to decline dramatically and computing power increases, governments, business and individuals are increasingly migrating their social and economic activities to the Internet. The digitalisation of the economy and society promises to spur innovation, generate efficiencies and improve services in a wide range of areas, from health to agriculture, public governance, tax, transport, international trade and investment, the financial system, education, and the environment. The successful transition to a digital economy is a necessary condition for boosting economic growth. Indeed, digital technologies contribute not only to innovation in products, but also to innovation in processes and organisational arrangements.

At the same time, digitalisation can be disruptive. It transforms organisations' front- and back-office processes and raises a number of important policy challenges including privacy, security, consumer policy, competition, taxation, innovation, finance, jobs and skills, to name but a few. Failure to adequately address these issues could lead to reactionary policies, a worsening of inequalities and a further erosion of the social fabric. A coherent and holistic policy approach is necessary to harness and leverage the benefits of digitalisation for growth and well-being, to support inclusive growth, and address global challenges like climate change, development and ageing populations.

This proposal concerns a multidisciplinary and cross-cutting project on *Seizing the Benefits of Digitalisation for Growth and Well-being* (hereafter referred to as Digitalisation of Economy and Society - DES), which aims to bring together the wide-ranging policy and analytical expertise of the OECD to pave the way towards achieving this objective. It builds on a proposal for such a horizontal project by the Chairs of the four STI Committees (CDEP, CSTP, CCP and CIIE) . It also builds on recent Ministerial meetings on science and technology policy (October 2015) and employment (January 2016). It will also draw on the June 2016 Digital Economy Ministerial organised by the CDEP in cooperation with the CCP, ELSAC and EDPC.

Box 2.2. **Seizing the benefits of digitalisation for growth and well-being: New horizontal OECD work** *(cont.)*

Moreover, the ongoing project on the Next Production Revolution (NPR), which examines the impact of a range of new technologies on various economic and social outcomes, would also feed into the DES project. Finally, the project would build on the New Approaches to Economic Challenges (NAEC) approach, providing a multidimensional perspective of digitalisation, with an explicit consideration of policy trade-offs and synergies.

The overall objective of the project would be to identify the policy options that would ensure the widespread benefits of the digital economy while at the same time addressing the challenges induced by digitalisation. The project would aim to develop a better sense of how digitalisation affects different sectors and policy areas, and to articulate policies that reflect this understanding. It would contribute to a new growth narrative that recognises the trade-offs between various factors, including the objective of improving productivity and the need to more widely share the benefits of growth. It would also enable the OECD – unique in its capacity to provide a whole-of-government perspective on complex policy challenges – to support discussions on digitalisation at the highest levels (e.g., MCM, G7, G20). The objective would be to craft a forward-looking narrative that is both comprehensive and specific with a clear delineation of trade-offs inherent to such a widespread transformation of economy and society. In that respect, the project would build on the "NAEC state of mind" that has been developed over the last several years and would employ many of the new tools and ways of work pioneered by this project, hence mainstreaming NAEC's lessons – asking hard questions, changing assumptions and the understanding of the economy, changing analytical approaches and changing the way the OECD works with pathfinding, horizontal efforts which are far-reaching and relevant.

In a nutshell, the project would represent a concerted effort by the OECD to address the fundamental challenge of how to respond to the rapid pace of technological and structural change induced by digitalisation by:

1. Assessing the effects of the transformational changes induced by digitalisation on society as a whole and on all parts of the global economy.
2. Identifying the expected benefits from and issues raised by digitalisation for governments, businesses and individuals.
3. Examining how strategies and policies can best address these transformations.

The deliverable from the project would be a whole-of-OECD report that would assess the state and effects of, the expected benefits from, and the issues raised by, digitalisation in different sectors and policy areas. It would also examine how, and to what extent, policies are addressing this transformation, and offer guidance for countries to further capitalise on digitalisation to meet the broader societal goals of inclusive growth and better lives. In particular, the work will harness OECD's horizontal capabilities to explore how the digital transformation is affecting policies. For example, as ICTs change both the mode and delivery of educational instruction decoupling it from a specific location, what will be the implications for school funding based on local taxes? A comprehensive final report would be delivered at the end of 2018 (or early in 2019), a draft narrative at the 2017 MCM, and an extensive interim report at the 2018 MCM, together with a range of sector- and subject-specific reports addressing select elements of the digitalisation agenda. This schedule could also support thematic work under the German Presidency of the G20.

The expected benefits/outcomes of this work would be a key strategic vision and policy strategy from the OECD on one of the fundamental challenges facing our economies and societies. This report would provide member countries and partners with state-of-the-art guidance on how to respond to digitalisation in a proactive manner and seize its benefits for growth and wellbeing. This would establish the OECD as the "go-to" organisation for guidance on whole-of-government policies related to digitalisation. It would therefore provide high value for money, by proving a coherent and integrated approach – instead of a piecemeal, fragmented one – to an issue that is rapidly becoming a major challenge in almost every area of OECD work.

Source: OECD, (2016a), *Proposed Cross cutting Project: Seizing the Benefits of Digitalization for Growth and Well-Being*, OECD document for official use, DSTI/IND/STP/ICCP/CP(2016)1.

Internet usage by individuals

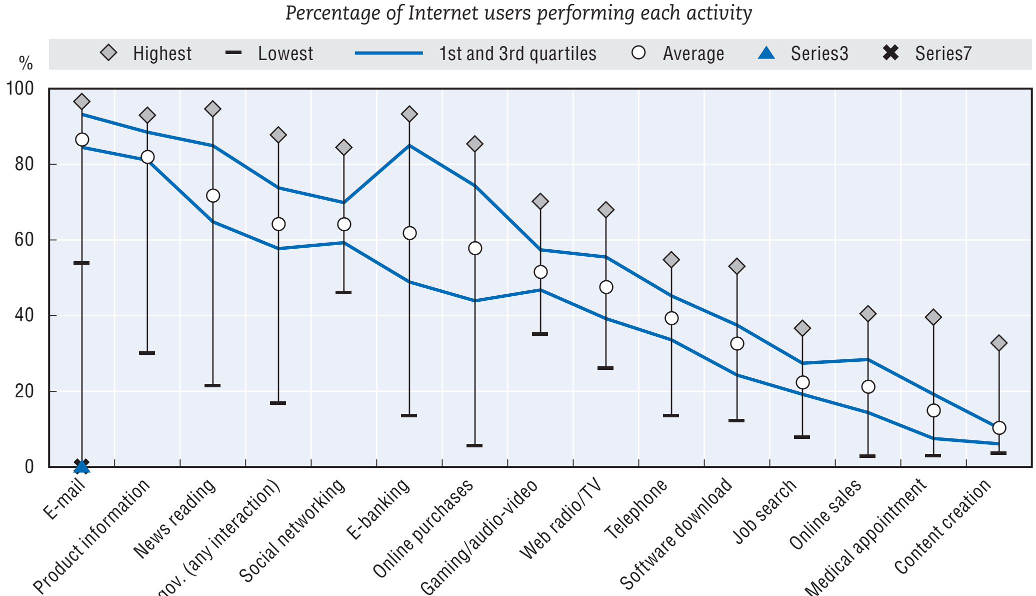
In 2014, 81% of the adult population in the OECD accessed the Internet, of whom over 75% used it on a daily basis. Developments in mobile technology have also enabled people to conduct daily personal computing and communications activities "on the go". In 2013, more than 40% of adults across the OECD used a mobile or smartphone to connect to the Internet.

Over the period 2013-14, on average 87% of Internet users reported sending e-mails, 82% used the Internet to obtain information on goods and products, and 72% read online news. While 58% of Internet users ordered products on line, only 21% sold products over the Internet (Figure 2.1). Levels of activities such as sending e-mails, searching product information or social networking show little variation across most countries. However, the share of Internet users performing activities usually associated with a higher level of education (e.g. those with cultural elements or more sophisticated service infrastructures), tend to show greater variation across countries. This is the case, for example, for e-banking, online purchases, news reading and use of e-government services.

The breadth of activities performed on the Internet can be regarded as an indication of user sophistication. In 2013, the average Internet user performed 6.3 out of 12 selected activities, up from 5.4 in 2009. This figure ranges from 7.5 to 8 activities in the Nordic countries and the Netherlands, to 5 activities or fewer in Greece, Italy, Korea, Poland and Turkey.

Figure 2.1. **The diffusion of selected online activities among Internet users, 2013-14**

Percentage of Internet users performing each activity



Notes: Unless otherwise stated, a recall period of three months is used for Internet users. For Australia, Canada, Chile, Japan, Korea, Mexico and New Zealand, the recall period is 12 months. For Switzerland, the recall period is six months. For the United States, no time period is specified. For web-based radio/television, data refer to 2012. For job search and software download categories, data refer to 2013. For online purchases and e-government categories, the recall period is 12 months instead of three months and data relate to individuals who used the Internet in the last 12 months instead of three months. For countries in the European Statistical System and Mexico, data refer to 2014. For Australia, Canada and New Zealand, data refer to 2012. For Chile, Israel and Japan, data refer to 2013. For Australia, Chile and New Zealand with regard to interactions with public authorities, data refer to obtaining information from public authorities. For Japan, data refer to individuals aged 15-69. For job search, data refer to 2012.

Sources: OECD, ICT Database; Eurostat, Information Society Statistics and national sources, April 2015, OECD (2015a), *Digital Economy Outlook*, OECD Publishing, Paris, p. 139. *http://dx.doi.org/10.1787/9789264232440-en*.

StatLink http://dx.doi.org/10.1787/888933224908

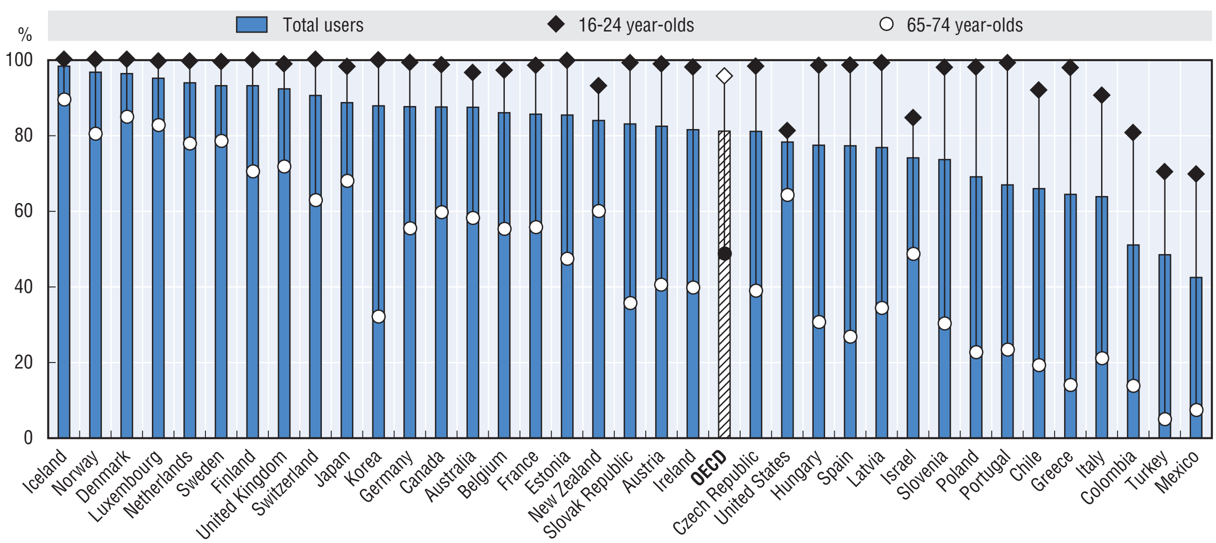
Education moulds digital behaviour

Internet usage continues to vary widely across OECD countries and social groups. In 2014, over 95% of the adult population accessed the Internet in Denmark, Iceland, Luxembourg and Norway, but less than 50% in Mexico and Turkey. In Iceland and Italy, the share of daily users is very similar to that of total users. In Chile, Japan and Mexico, however, many users access the Internet on an infrequent basis.

Differences in Internet uptake are linked primarily to age and education, often combined with income levels. In most countries, uptake by young people is nearly universal, but there are wide differences for older generations (Figure 2.2). Over 95% of 24-year-olds in the OECD used the Internet in 2014 against less that 49% of 65-74 year-olds.

Figure 2.2. **Internet users by age, 16-24 year-olds and 65-74 year-olds, 2014**

As a percentage of population in each age group



Notes: Unless otherwise stated, Internet users are defined for a recall period of 12 months. For Switzerland, the recall period is six months. For the United States, no time period is specified. For the United States, data refer to individuals aged 18 and over living in a house with Internet access, and to age intervals of 18-34 (instead of 16-24) and 65 and over, (instead of 65-74). Data are sourced from the US Census Bureau. For Australia, data refer to 2012/13 (fiscal year ending in June 2013) instead of 2013, and to individuals aged 65+ instead of 65-74. For Canada, Japan and New Zealand, data refer to 2012 instead of 2014. For Chile, Israel, the United States and Colombia, data refer to 2013 instead of 2014. For Israel, data refer to individuals aged 20 and over (instead of 16-74) and 20-24 (instead of 16-24). For Colombia, data refer to individuals of 12 years old and above (instead of 16-74) 12-24 year-olds (instead of 16-24), and 55 year-olds and over (instead of 65-74). For Japan, data refer to 15-69 year-olds (instead of 16-74), 15-28 year-olds (instead of 16-24) and 60-69 year-olds (instead of 65-74).

Sources: OECD, ICT Database; Eurostat, Information Society Statistics and national sources, March 2015, OECD (2015a), *Digital Economy Outlook*, OECD Publishing, Paris, p. 138. *http://dx.doi.org/10.1787/9789264232440-en*.

StatLink *http://dx.doi.org/10.1787/888933224896*

Education appears to be a much more important factor among older people than for younger adults. Usage rates for 65-74 year-olds with tertiary education are generally in line with those of the overall population, and in some countries approach the usage rates among 16-24 year-olds. The difference in usage between 65-74 year-olds with high and low educational attainment are particularly large in Hungary, Poland and Spain (OECD, 2014).

Education also plays also a key role in shaping the range of activities on the Internet. While users with tertiary education perform on average 7.3 different activities, those with lower secondary education and below perform only 4.6 activities. Differences by level of education are particularly high for Belgium, Hungary, Ireland, Korea and Turkey.

Digital practices among 15-year-olds

Digital devices and the internet have become a particularly important and powerful component of young people's lives. For education it is very important to have a good understanding of the digital practices and behaviours of students. As part of the OECD's Programme for International Student Assessment (PISA), the 2012 cycle examined the use of computers and the internet among 15-year old students (Box 2.3).

Box 2.3. **How information on students' familiarity with ICT was collected in the PISA 2012 survey**

PISA collects internationally comparable information on students' access to and use of computers and their attitudes towards the use of computers for learning. In PISA 2012, 29 OECD countries and 13 partner countries and economies chose to distribute the optional ICT familiarity component of the student questionnaire. In 2012, this component contained 12 questions, some of which were retained from the previous PISA survey (2009) to allow for comparisons across time. New questions focus on the age of first use of computers and the Internet; the amount of time spent on the Internet; and, since mathematics was the major domain assessed in PISA 2012, on the use of computers during mathematics lessons.

The OECD countries that participated were Australia, Austria, Belgium, Chile, the Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland and Turkey. The partner countries and economies that participated were Costa Rica; Croatia; Hong Kong, China; Jordan; Latvia; Liechtenstein; Macau, China; the Russian Federation; Serbia; Shanghai, China; Singapore; Chinese Taipei and Uruguay.

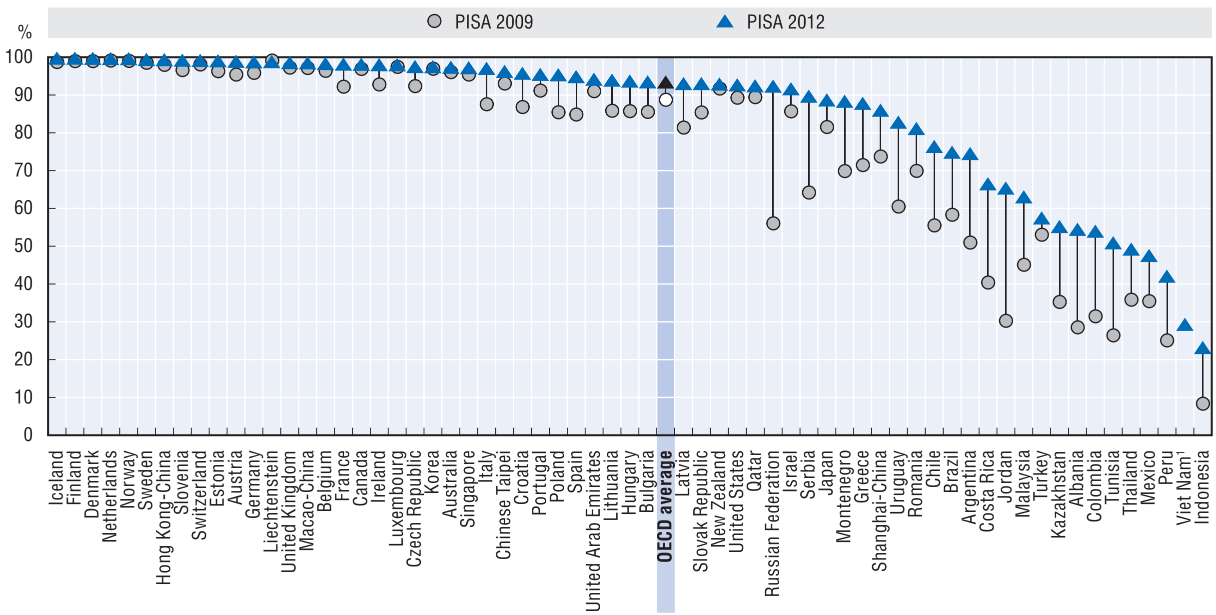
With the exception of Costa Rica; Mexico; Shanghai, China and Chinese Taipei, all the other countries and economies taking part had also distributed the ICT familiarity module as part of the student questionnaire in 2009. Trends based on this module are therefore available for 28 OECD countries and 10 partner countries and economies. The main student and school questionnaires also collected additional information on the availability and use of ICT at home and at school, as well as about school policies on using ICT, which is available for all participants in PISA 2012. In the student questionnaire, students answered questions on whether or not they have a home computer to use for schoolwork, educational software and a link to the Internet; how many computers they have at home; whether they programme computers; and how many hours, on average, they spend repeating and training on content from school lessons by working on a computer (e.g. learning vocabulary with training software). As part of the school questionnaire, principals provided information on the availability of computers at their schools and on whether they feel that a lack of computers hindered instruction in their school. A new question in PISA 2012 also asked school principals to report on the extent to which students are expected to access the Internet to perform school-related work.

Source: OECD (2015b), *Students, Computers and Learning: Making the Connection*, *http://dx.doi.org/10.1787/9789264239555-en*, p. 33.

Data collected from students participating in the PISA assessment show that by 2012, computers were present in almost every household across most OECD countries, and often in large numbers. On average across OECD countries, only 4% of 15-year-old students lived in homes with no computer, and 43% of them lived in homes with three or more computers.

However, this country average masks large disparities. For instance, among OECD countries, 42% of students in Mexico and 29% of students in Turkey did not have a computer in their homes (and these shares exclude 15-year-olds who are not in school). Meanwhile, more than half of students in the partner countries Indonesia (74%) and Viet Nam (61%) did not have a computer at home. In these countries, the so-called "first digital divide", between "have" and "have nots", has not yet been closed (OECD, 2015b).

Figure 2.3. **Change in Internet access at home, 2009-12**



1. PISA 2009 data are missing for Viet Nam.

Note: White symbols indicate differences between PISA 2009 and PISA 2012 that are not statistically significant.
Countries and economies are ranked in descending order of the percentage of students accessing the Internet at home in 2012.

Source: OECD, PISA 2012 database, Table 1.2.

StatLink http://dx.doi.org/10.1787/888933252605

Between 2009 and 2012, more students gained access to computers, and the share of students with no computer at home declined. In 49 out of the 63 countries and economies with comparable data for both years, the number of computer-equipped households increased, and where it did not – sometimes because almost all students already had computers at home by 2009 – the number of home computers to which students had access increased. For instance, in Albania, Argentina, Brazil and Colombia, the share of students with a computer at home increased by 15 percentage points or more. In Denmark, Iceland, the Netherlands, Norway and Sweden, where fewer than 1% of 15-year-old students had no computer at home in 2009, the share of students who reported having more than three home computers increased by around 10 percentage points or more over the three-year period. By 2012, more than two out of three students in these countries had three computers or more at home.

Home ICT devices today are mostly used to access services offered on the Internet, such as computer-mediated communication (Internet telephony, e-mail, instant messaging, chat, etc.), web-based services (social networks and online community services, news websites, e-commerce, online banking, etc.) and cloud computing services based on data transfer systems (software-as-a-service, file storage, video streaming, etc.). Many of these services can support formal and informal learning. As a result, home computers or mobile devices connected to the Internet also offer users a host of educational resources, both in terms of content and applications, and often for free. Without a connection to the Internet, students have only limited, if any, ICT tools to support collaboration and they do not have access to online encyclopaedias or other multimedia content in native and foreign languages. An Internet connection at home thus represents a substantial increase in the educational resources available to students.

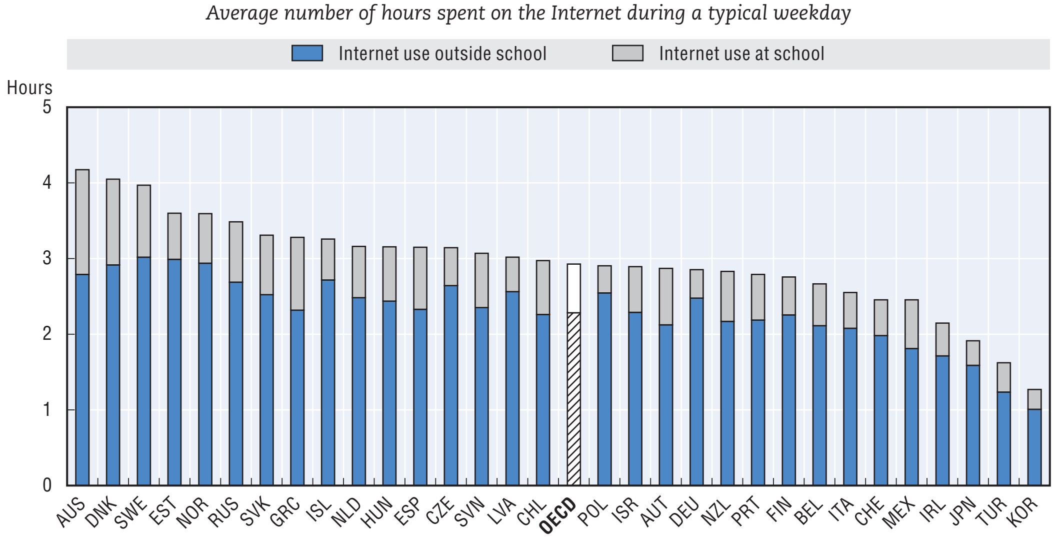
Figure 2.3 shows the percentage of students in each country who reported having access to the Internet at home. On average across OECD countries, 93% of students reported that they had Internet access at home. In Denmark; Finland; Hong Kong, China; Iceland; the Netherlands; Norway; Slovenia; Sweden and Switzerland, at least 99% of students' homes had Internet access. Only in five of the countries that participated in the PISA 2012 survey – Indonesia, Mexico, Peru, Thailand and Viet Nam – did fewer than one in two homes have Internet access.

For the first time, PISA 2012 measured how much time, within a typical school week, students spend using the Internet at school and at home, both on school days and during weekends. Because the answers were given on a categorical scale, it is not possible to compute exactly the average time students spend on line. However, it is possible to establish with confidence a lower bound for the number of minutes students spend on online activities, for instance converting the answer "between one and two hours", into "at least 61 minutes". Self-reports show that, on average across OECD countries, students typically spend over two hours on line each day on school days as well as during weekends.

Figure 2.4 demonstrates that the 15-year-olds spent the most time on Internet activities outside school. On average across OECD countries 15-year-olds spent about 2.29 hours per day on the internet outside school, and only 0.64 hours at school.

Figure 2.4. **Internet use among 15 year-old students at school and outside school, 2012**

Average number of hours spent on the Internet during a typical weekday



Source: OECD, PISA 2012 Database, May 2014.

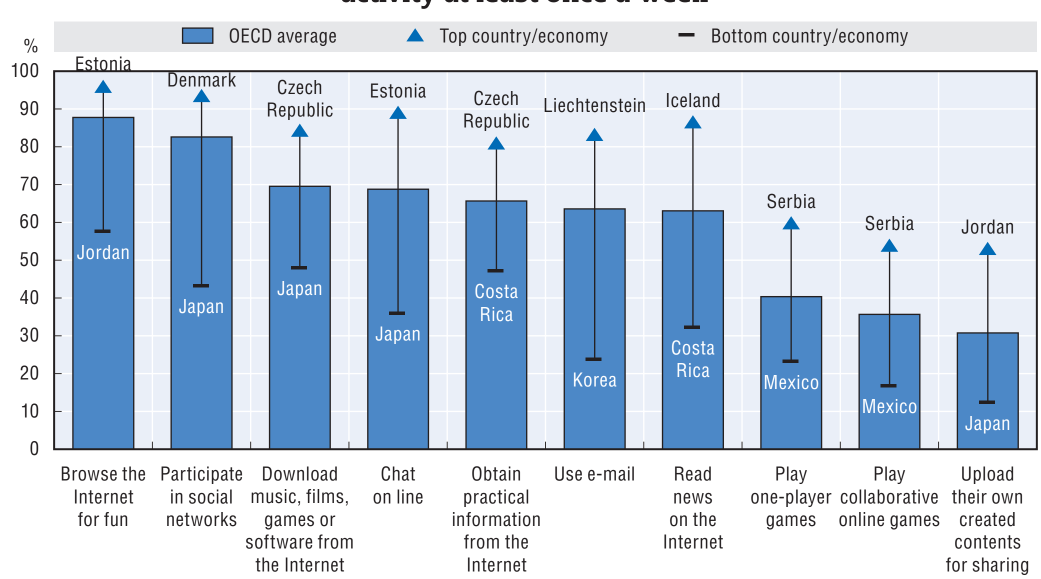
StatLink http://dx.doi.org/10.1787/888933148275

In Australia, Denmark, Estonia, Norway, the Russian Federation and Sweden, more than one in four students spend over four hours per weekday on line outside of school. On average, students in these countries, and in the Czech Republic and Iceland, spend at least two hours (120 minutes) on line outside of school, during weekdays. During weekends, more than 40% of students spend more than four hours per day on line in Denmark; Estonia; Macau, China; Norway and Sweden. At the opposite extreme are Ireland, Italy, Korea, Mexico and Turkey, where this share is below 20%, and about 60% or more students spend less than two hours on line during a typical weekend day. In Mexico and Turkey the lack of Internet access at home may represent the main constraint, but in Ireland, Italy and Korea, very few students have no Internet access at home, and most students use the Internet at least to some extent. Assuming that weekends are mostly devoted to social activities, these must not (yet) take place on line in these countries.

In PISA 2012, students were asked how often they use a computer outside of school for ten different leisure tasks (six of which were included in the PISA 2009 questionnaire). In the following section, students who reported that they engage in any activity at least once a week are considered frequent users of computers for that task.

Across OECD countries, the most common leisure activity using computers is browsing the Internet for fun. Some 88% of students do this at least once a week. This is followed by participating in social networks (83% of students); downloading music, films, games or software from the Internet (70%); and chatting on line (69%). More than half of students also use the Internet at least weekly to obtain practical information (66%), read or send e-mails (64%), or read news on the Internet (63%). Two-fifths of students (40%) also play one-player games on computers, while 36% play online collaborative games. Only 31% of students use computers at least once a week to upload their own content, such as music, poetry, videos or computer programmes (Figure 2.5).

Figure 2.5. **Percentage of students who reported engaging in each Internet activity at least once a week**



Source: OECD, PISA 2012 database, Table 1.6.

StatLink http://dx.doi.org/10.1787/888933252645

Among the activities listed in both the 2009 and 2012 questionnaires, e-mail and chat use are on the decline, probably replaced by the use of social networking services and other web-based messaging tools. Participation in social networks was more popular than sending e-mail or using chat in 2012, but was not among the activities listed in the 2009 PISA questionnaire. Thus this trend does not reflect a decline in the use of ICT for communication and sharing interests, but rather a convergence of different forms of communication on new integrated platforms that require greater bandwidths. A second trend shows a decline in one-player games, which is partly offset by the emergence of online collaborative games. In contrast, the share of students who frequently browse the Internet for fun or download music, films, games or software from the Internet has increased significantly.

Is the usage of digital devices and the internet by 15-year-old students influenced by their socio-economic background? The expression "digital divide" was coined to describe the disparities in the ease with which people access and use information and communication technologies – and the threat to social and national cohesion implicit in that divide. Those left behind on the analogue side of the divide may not be able to improve their productivity at work or participate fully in civic affairs. And that, in turn, will only widen the divide.

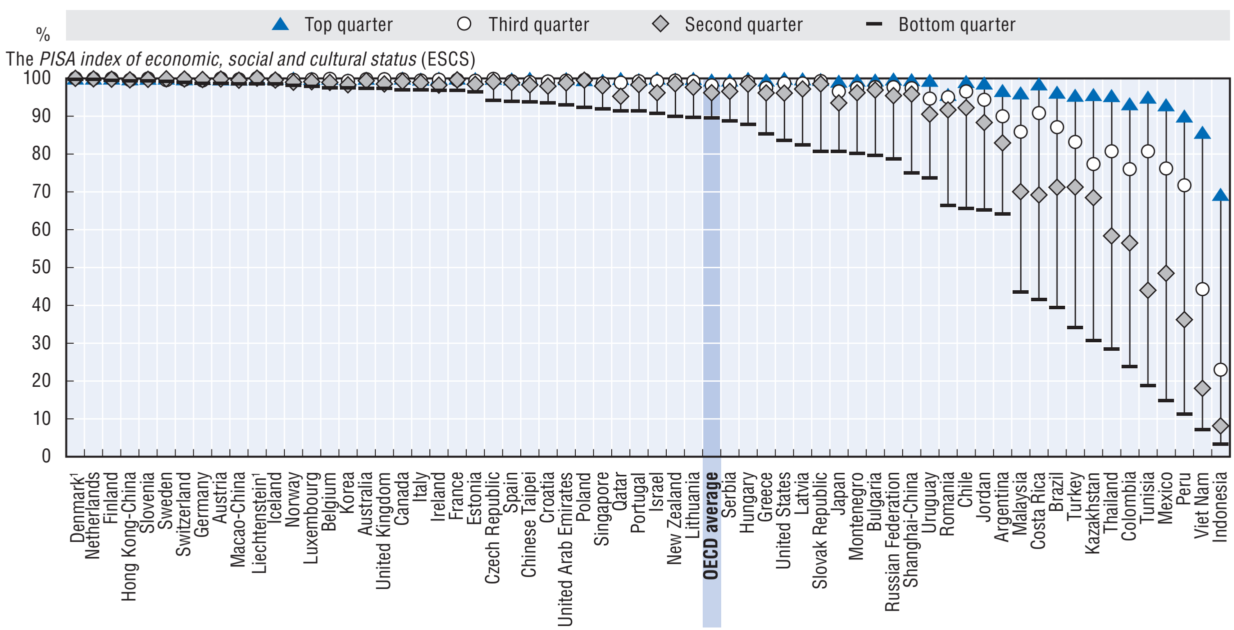
In recent years, much progress has been made in ensuring that all students, irrespective of their parents' wealth and occupation, have access to the Internet. And, indeed, as shown in Figure 2.6, in a large group of countries there is now no or almost no difference in access to the Internet between students in the upper quarter of the PISA index of economic, social and cultural status (ESCS) and the bottom quarter. In Denmark; Finland; Hong Kong, China; Iceland; the Netherlands; Norway; Sweden and Switzerland, fewer than 2% of disadvantaged students – who are defined as the 25% of students with the lowest socio-economic status – do not have access to the Internet at home.

On the other hand, there still are several countries – even high-income countries – where social disparities still have a high impact, including Israel, the United States and Japan. Where such large disparities in home Internet access persist, schools often play an important role in ensuring that all students have access to ICT resources. Among the most disadvantaged, 50% of students in Turkey, 45% in Mexico, 40% in Jordan and 38% in Chile and Costa Rica only have access to the Internet thanks to their school.

In contrast, PISA data also show that the amount of time students spend on line during weekends does not differ across socio-economic groups on average across OECD countries. Interestingly, the gap is reversed in 16 out of 29 OECD countries, with students from poorer families spending more time on line than those from wealthier families. Disadvantaged students spend at least 15 more minutes per day on line during weekends than advantaged ones in Belgium; Germany; Korea; Shanghai, China; Switzerland and Chinese Taipei.

When the frequency and variety of computer use for leisure, outside of school, are summarised in an index, differences are mostly limited to countries with large gaps in access. In Costa Rica, Jordan and Mexico, the most advantaged students (those from the top quarter by socio-economic status) use computers for leisure more than the OECD average, while students from the bottom quarter are more than one standard deviation below this benchmark. At the same time, in Belgium, Finland, Germany, Sweden, Switzerland and Chinese Taipei, there are no significant differences across socio-economic groups in the average leisure use of ICT outside of school.

Figure 2.6. **Access to computers at home and students' socio-economic status**



1. The difference between the top and the bottom quarter of ESCS is not statistically significant.

Countries and economies are ranked in descending order of the percentage of students in the bottom quarter of ESCS who have a connection to the Internet at home.

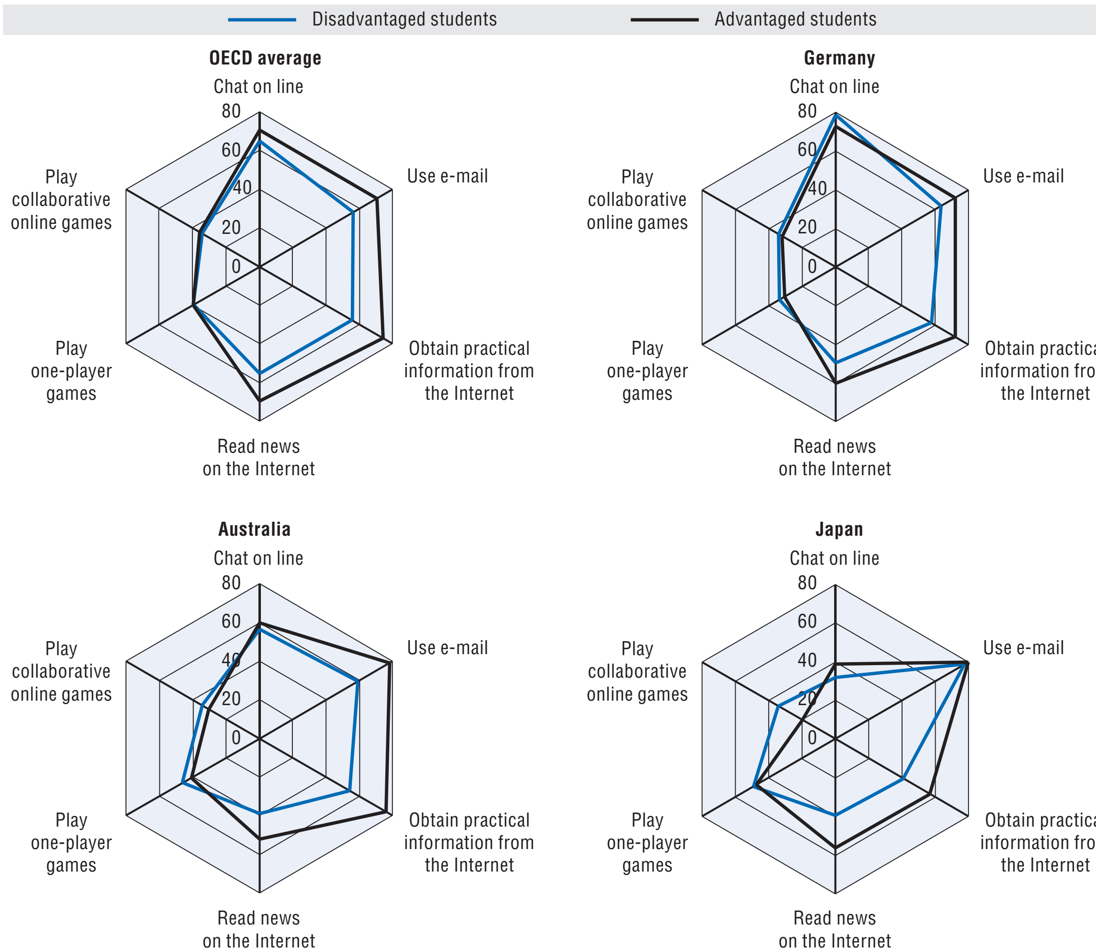
Source: OECD, PISA 2012 Database, Table 5.1a.

StatLink http://dx.doi.org/10.1787/888933253134

However, the specific activities for which students use computers in their free time differ across socio-economic groups. In general, disadvantaged students tend to prefer to use chat rather than e-mail, and to play video games rather than read the news or obtain practical information from the Internet. Across OECD countries, a similar proportion of advantaged students (70%) use e-mail and online chats at least once a week, whereas on average, disadvantaged students are more likely to use online chat than e-mail: 65% compared to 56%. And while in most countries/economies there are no differences related to socio-economic status in the use of video games, the influence of socio-economic status is strong when it comes to reading news or obtaining practical information from the Internet (Figure 2.7).

Figure 2.7. **Common computer leisure activities outside of school, by students' socio-economic status**

OECD average values and values for selected countries



Notes: The figure shows the percentage of students who engage in each of the selected activities at least once a week. Socio-economically disadvantaged students refers to students in the bottom quarter of the *PISA index of economic, social and cultural status* (ESCS); socio-economically advantaged students refers to students in the top quarter of ESCS.

Source: OECD, PISA 2012 Database, Table 5.11.

StatLink http://dx.doi.org/10.1787/888933253203

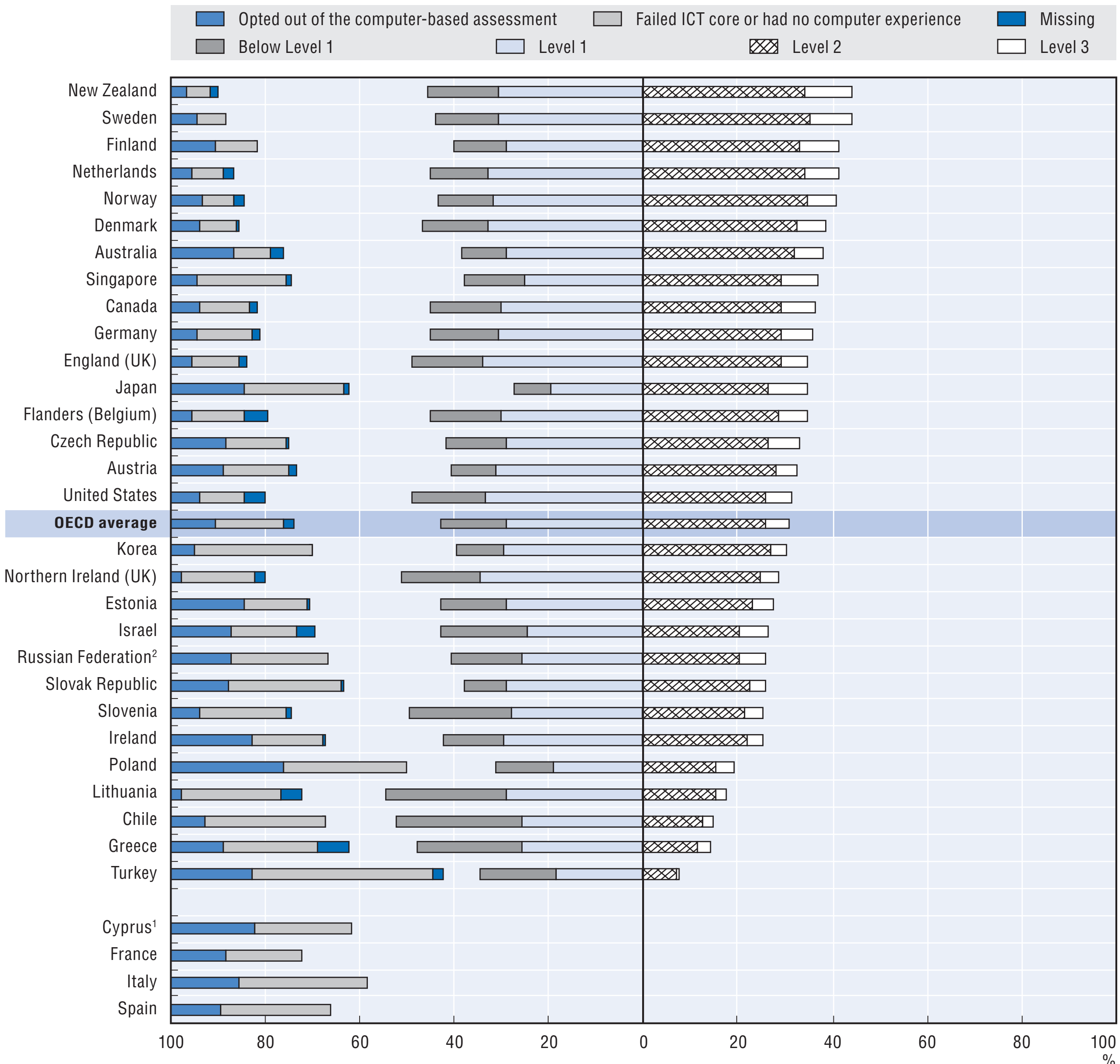
Digital skills in the adult population

Proficiency in problem solving in technology-rich environments

The education gradient in various measures of internet and ICT usage raises the question about the digital skills in the population. What do we know about the adults' proficiency with technology and digital devices?

To understand how well-equipped adults are to manage information in digital environments, the Survey of Adult Skills (Box 2.4), a product of the OECD Programme for the International Assessment of Adult Competencies (PIAAC), includes an assessment of problem solving in technology-rich environments. This assessment measures adults' abilities to solve the types of problems they commonly face as ICT users in modern societies. The assessment includes problem-solving tasks that require the use of computer applications, such as e-mail, spreadsheets, word-processing applications and websites that adults often encounter in daily life. The survey also collects information on the frequency with which adults use different types of ICT applications, both at work and in their daily lives.

Figure 2.8. **Problem-solving proficiency in technology-rich environments among adults**



1. Note by Turkey:
The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".
Note by all the European Union Member States of the OECD and the European Union:
The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.
2. The sample for the Russian Federation does not include the population of the Moscow municipal area.

Notes: Adults included in the missing category were not able to provide enough background information to impute proficiency scores because of language difficulties, or learning or mental disabilities (referred to as literacy-related non-response). The missing category also includes adults who could not complete the assessment of problem solving in technology-rich environments because of technical problems with the computer used for the survey. Cyprus, France, Italy, Jakarta (Indonesia) and Spain did not participate in the problem solving in technology-rich environments assessment. Results for Jakarta (Indonesia) are not shown since the assessment was administered exclusively in paper and pencil format.
Countries and economies are ranked in descending order of the combined percentages of adults scoring at Level 2 and at Level 3.

Source: Survey of Adult Skills (PIAAC) (2012, 2015), Table A2.6.

StatLink http://dx.doi.org/10.1787/888933365903

The survey provides two different, albeit related, pieces of information about the capacity of adults to manage information in technology-rich environments. The first is the proportion of adults who have sufficient familiarity with computers to use them to perform information-processing tasks. The second is the proficiency of adults with at least some ICT skills in solving the types of problems commonly encountered in their roles as workers, citizens and consumers in a technology-rich world.

The results of the survey (Figure 2.8) show that in each participating country/economy, a substantial proportion of adults were unable to display any proficiency in problem solving in technology-rich environments since they took the assessment in the paper-based format. Three separate groups of adults fall into this category: adults with no computer experience, those who failed the "ICT core" test and thus did not have basic computer skills needed for the computer-based assessment, and adults who opted to take the paper-based version of the assessment even though they reported having previous computer experience.

Overall, around one in ten adults (10.0%) reported having no prior computer experience. This ranged from less than 2% in Sweden (1.6%) and Norway (1.6%) to more than one in three adults in Turkey (35.6%) and more than one in five adults in Italy (24.4%) and the Slovak Republic (22.0%). A further 4.7% of adults did not have the basic skills that were assessed by the ICT core test, such as the capacity to use a mouse or scroll through a web page. This was true of around 2% of adults in Cyprus (1.9%), the Czech Republic (2.2%) and the Slovak Republic (2.2%), compared with larger proportions of adults in Japan (10.7%), Korea (9.1%), Chile (7.8%) and Singapore (7.1%) (OECD, 2016). Thus, around one in four adults has no or only limited experience with computers or lacks confidence in their ability to use computers. In addition, nearly half of all adults are proficient only at or below Level 1 in problem solving in technology-rich environments. This means they can only use familiar applications to solve problems that involve few steps and explicit criteria, such as sorting e-mails into pre-existing folders.

On the other hand, across the OECD countries that participated in the survey, one-third of adults score at the highest levels on the proficiency scale (Level 2 or 3). These adults can solve problems that require the co-ordinated use of several different applications, can evaluate the results of web searches, and can respond to occasional unexpected outcomes. The Nordic countries and the Netherlands have the largest proportions of adults (around 40%) who score at the highest levels of proficiency. Ireland, Poland and the Slovak Republic have the smallest proportions of adults (around 20%) who score at these levels.

Proficiency varies enormously between social categories within countries. Educational attainment and age have an especially strong impact on the distribution of digital skills (Figure 2.9).

Only about 7% of low-educated adults) scored at Level 2 or 3 on the problem-solving assessment, compared to 48% of adults who had attained tertiary education. In this area, the differences between countries and economies are small. The share of low-educated adults with high proficiency in problem solving in technology-rich environments is below 3% in a large and diverse group of countries that includes Chile, Greece, Ireland, Korea, Poland, Singapore, the Slovak Republic, Turkey and the United States, and exceeds 10% in only five countries (Australia, Denmark, the Netherlands, New Zealand and Norway). There is much more variation at the bottom of the proficiency distribution, however. An average of 41% of low-educated adults reported having no experience at all with ICTs, or failed the ICT core test. This share ranges from more than 70% in Korea, Poland and the Slovak Republic, and around 60% in Chile, Israel, Singapore, Slovenia and Turkey, to 48% in Greece, and below 20% in a large number of countries, including New Zealand, Norway and Sweden.

Box 2.4. **About the OECD Survey of Adult Skills**

The Survey of Adult Skills, a product of the OECD Programme for the International Assessment of Adult Competencies (PIAAC), assesses the proficiency of adults aged 16-65 in literacy, numeracy and problem solving in technology-rich environments. These three domains are key information-processing competencies that are relevant to adults in many social contexts and work situations. They are necessary for full integration and participation in the labour market, education and training, and social and civic life.

The Survey of Adult Skills also collects information about a number of factors in each respondent's background and context. This information includes participation in activities that use the competencies assessed in the three domains, such as the frequency of reading different kinds of material or using different types of information and communications technology (ICT). The survey includes questions about the use of various generic skills at work, such as collaborating with others and organising one's time. Respondents are also asked whether their skills and qualifications match their work requirements and whether they have autonomy with respect to key aspects of their work.

The first survey was conducted in 2011-12 in 24 countries and sub-national regions: 22 OECD member countries or regions – Australia, Austria, Belgium (Flanders), Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Japan, Korea, the Netherlands, Norway, Poland, the Slovak Republic, Spain, Sweden, the United Kingdom (England and Northern Ireland), and the United States; and two partner countries – Cyprus* and the Russian Federation**. Around 166 000 adults were surveyed during this first cycle. Nine countries took part in a second round of the assessment in 2014-15: Chile, Greece, Indonesia, Israel, Lithuania, New Zealand, Singapore, Slovenia and Turkey. A total of 50 250 adults were surveyed. In all countries except Indonesia the entire national population was covered. In Indonesia, data were only collected in the Jakarta municipal area.

The survey is administered under the supervision of trained interviewers, most often in the respondent's home. It starts with a background questionnaire, delivered in computer-aided personal interview format by the interviewer, and typically takes 30-45 minutes to complete. Assessment of the domain competencies is conducted either on a laptop computer or by completing a paper version, depending on the respondent's computer skills. The respondents usually take 50 minutes to complete the assessments, but there is no time limit. To reduce the time required for the survey, respondents are assessed in only one or two of the three domains, not in all of them. Respondents with very low literacy skills take an alternative assessment of basic reading skills.

The problem-solving and basic-reading assessments are optional for countries; in the first cycle, several countries declined to participate in those parts of the survey (Cyprus*, France, Italy and Spain). The survey is given in the official language or languages of each participating country, sometimes also including a widely-spoken minority or regional language. Sample sizes depend on the number of cognitive domains assessed, the number of languages used, and decisions by countries about whether to increase the sample sizes to allow more precise estimates for individual geographic regions or population subgroups. In the first cycle of the survey, the samples ranged from about 4 500 to about 27 300 adults.

During the process of scoring the assessment, a difficulty score is assigned to each task, based on the proportion of respondents who complete it successfully. These scores are represented on a 500-point scale. Respondents are placed on the same 500-point scale, using the information about the number and difficulty of the questions they answer correctly. At each point on the scale, an individual with a proficiency score of that particular value has a 67% chance of successfully completing test items located at that point. The same individual will also be able to complete more difficult items with a lower probability of success and easier items with a greater chance of success. To help interpret the results, the reporting scales are divided into four proficiency levels (Below Level 1 through to Level 3) in the problem solving in technology-rich environments domain. In addition to the four proficiency levels, there are three additional categories (no computer experience, failed ICT core and opted out) for those adults who were not able to demonstrate their proficiency in this domain due to lacking the basic computer skills needed to sit the assessment.

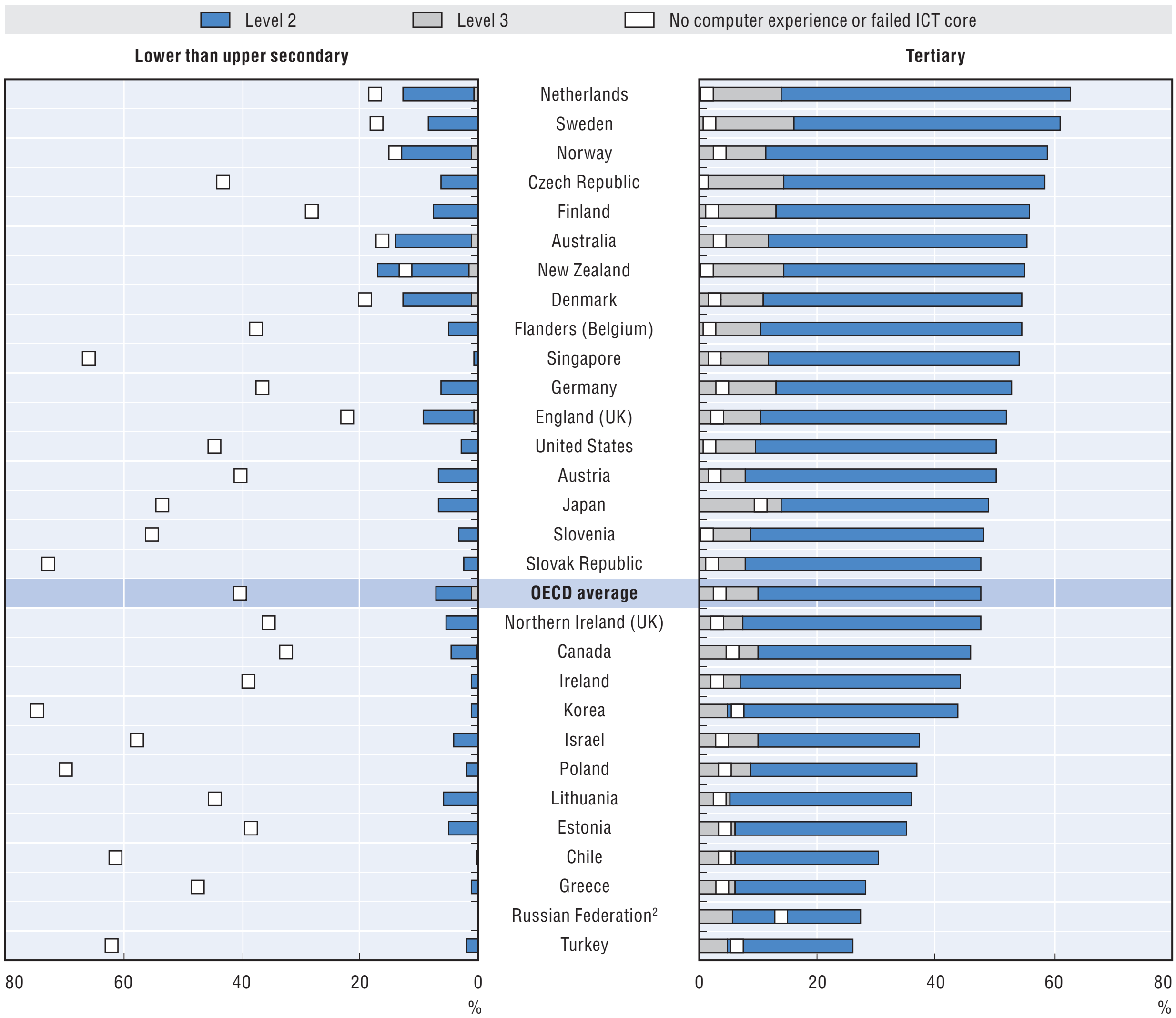
*see note 1 for Figure 2.8.

**In the Russian Federation, the data do not cover the Moscow municipal area.

Source: OECD (2016b), *Skills Matter: Further Results from the Survey of Adult Skills,* OECD Skills Studies, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264258051-en*

Figure 2.9. **Problem-solving proficiency, by educational attainment**

Percentage of low- and high-educated adults scoring at Level 2 or 3 in problem solving in technology-rich environments, or having no computer experience (adults aged 25-65)



1. See note 1 for Figure 2.8.

2. *The sample for the Russian Federation does not include the population of the Moscow municipal area.*

Notes: Percentages on the problem solving in technology-rich environments scale are computed so that the sum of percentages for the following mutually exhaustive categories equals 100%: opted out of the computer-based assessment; no computer experience; failed ICT core test; below Level 1, Level 1, Level 2 and Level 3. For more detailed results for each category, see corresponding table mentioned in the source below. Lower than upper secondary includes ISCED 1, 2 and 3C short. Upper secondary includes ISCED 3A, 3B, 3C long and 4. Tertiary includes ISCED 5A, 5B and 6. Where possible, foreign qualifications are included as the closest corresponding level in the respective national education systems. Cyprus[1], France, Italy, Jakarta (Indonesia) and Spain did not participate in the problem solving in technology-rich environments assessment.

Countries and economies are ranked in descending order of the combined percentages of adults with tertiary attainment scoring at Level 2 or 3.

Source: Survey of Adult Skills (PIAAC) (2012,2015), Table A3.3 (P).

StatLink http://dx.doi.org/10.1787/888933365994

When looking at highly educated adults, the opposite pattern emerges: there are much more pronounced differences between countries at the economy at the top than at the bottom of the proficiency distribution. The share of tertiary-educated adults who failed the ICT core test, or who reported having no ICT experience, ranges from 2% in New Zealand

and Slovenia to 7% in Turkey (and 12% in Japan). By contrast, less than 30% of high-educated adults in Greece and Turkey scored at Level 2 or higher, compared to between 54% and 63% in ten other countries/economies, including Australia, the Netherlands, New Zealand, Singapore and Sweden.

Age-related differences in proficiency are very pronounced when it comes to problem solving in technology-rich environments. This assessment relied on familiarity with ICT to a greater extent than the assessments of literacy and numeracy. Given that the widespread use of ICT is a relatively recent phenomenon, older adults were clearly in a position of relative disadvantage compared to younger adults, as indicated by the large share of 55-65 year-olds who skipped the problem-solving assessment because of lack of computer experience, or because they failed the ICT core test. Moreover, the rate of penetration of ICT varies widely across countries. Although levels of use are converging, differences between countries remain.

This is well illustrated in Figure 2.10. On average, some 45% of 25-34 year-olds scored at Level 2 or 3 in the problem-solving assessment, compared to only 11% of older adults. However, proficiency in problem solving in technology-rich environments among younger adults varies widely across countries. In Chile, Greece and Turkey, between 12% and 24% of respondents scored at Level 2 or 3, compared to 55% or more in Denmark, the Netherlands, New Zealand, Norway, Singapore and Sweden, and to 67% in Finland. In New Zealand, 24% of older adults scored at Level 2 or 3, but in most other countries this share was smaller than 10%.

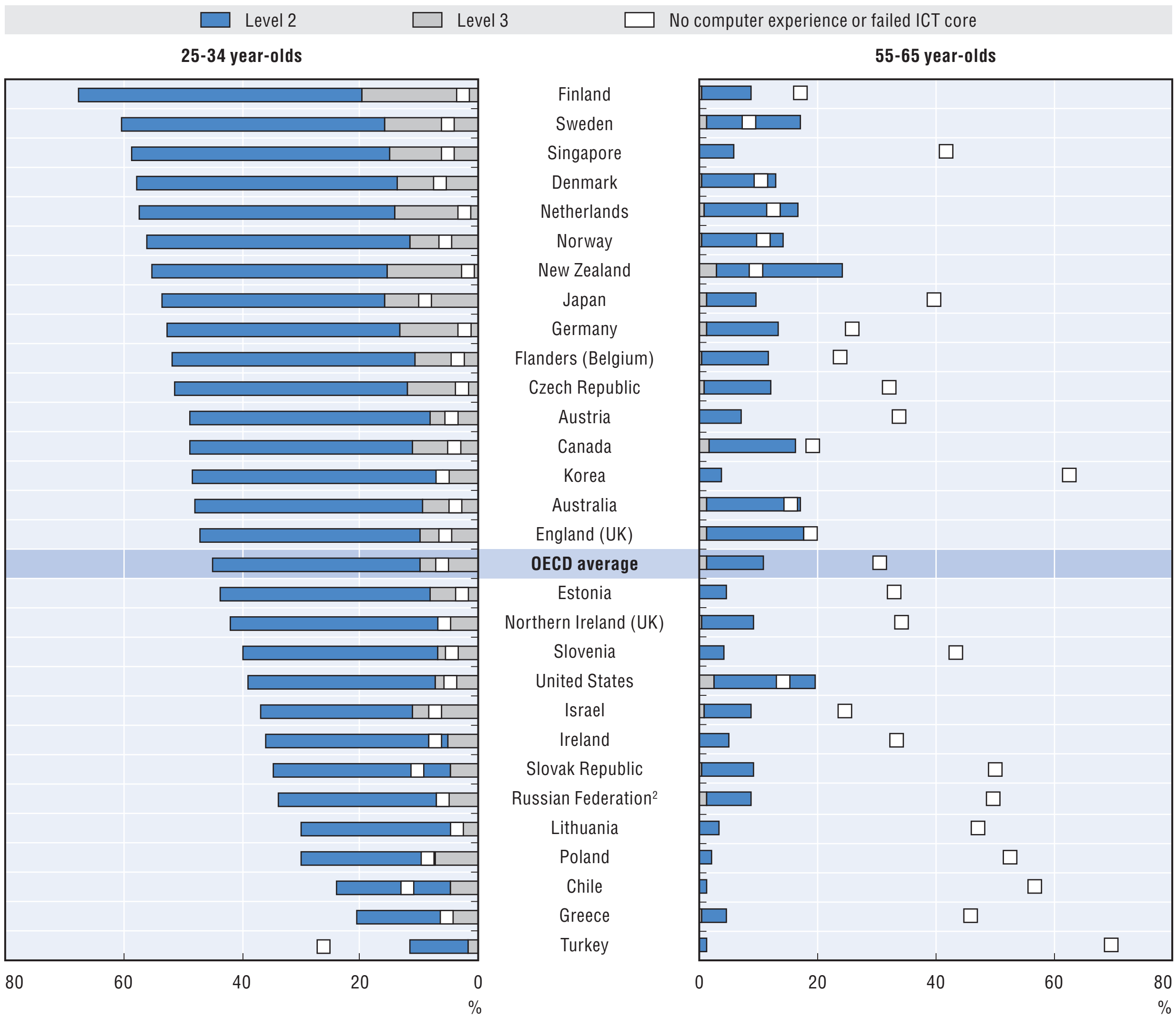
At the same time, few 25-34 year-olds skipped the problem-solving assessment because of a lack of computer experience, or because they failed the ICT core test (well below 10% in most countries, although 27% in Turkey). Lack of familiarity with ICT, however, constituted a major obstacle for older adults. On average, 32% of 55-65 year-olds were not able to take the assessment; but this share ranged from about 10% in New Zealand and Sweden to almost 50% in Greece and Lithuania, almost 60% in Chile, and 71% in Turkey.

In contrast to age and educational attainment, gender differences in digital skills are small, although men tend to have a slight advantage over women. On average, 33% of men scored at Level 2 or 3, compared to 29% of women. However, the proportions of men and women who have no computer experience, or who failed the ICT core test, is much more balanced, and is even slightly larger among men in a number of countries/economies. Only in Turkey, and to a lesser extent in Greece, are women significantly more likely to lack computer experience or to have failed the ICT core test.

Socio-economic background also matter a lot in this area. There is a strong correlation between parents' education and the probability of performing at Level 2 or 3 in problem solving in technology-rich environments. On average across OECD countries, the share of adults who are proficient at these levels is 38 percentage points larger among those with at least one parent who had attained tertiary education than it is among adults with neither parent having attained upper secondary education. The differences in these proportions range from 30 percentage points in Australia to 52 percentage points in the Czech Republic.

Figure 2.10. **Problem-solving proficiency among younger and older adults**

Percentage of adults aged 25-34 and 55-64 scoring at Level 2 or 3 in problem solving in technology-rich environments, or having no computer experience



1. See note 1 for Figure 2.8.

2. *The sample for the Russian Federation does not include the population of the Moscow municipal area.*

Notes: Percentages on the problem solving in technology-rich environments scale are computed so that the sum of percentages for the following mutually exhaustive categories equals 100%: opted out of the computer-based assessment; no computer experience; failed ICT core test; below Level 1, Level 1, Level 2 and Level 3. For more detailed results for each category, see corresponding table mentioned in the source below. Cyprus[1], France, Italy, Jakarta (Indonesia) and Spain did not participate in the problem solving in technology-rich environments assessment.

Countries and economies are ranked in descending order of the combined percentages of adults aged 25-34 scoring at Level 2 or 3.

Source: Survey of Adult Skills (PIAAC) (2012, 2015), Table A3.7 (P).

StatLink http://dx.doi.org/10.1787/888933366049

Immigration status and language background are also significantly correlated with the probability of performing at Level 2 or 3 in the problem solving in technology-rich environments assessment. Some 36% of native-born, native-language adults are proficient at Level 2 or 3 in the domain compared to 17% of foreign-born, foreign-language adults. The difference in the proportions of adults performing at those levels ranges from 5 percentage points in Ireland to 31 percentage points in Sweden. Most of the variation between countries comes in the proportion of native-born, native-language adults who are proficient at

Level 2 or 3. For example, foreign-born, foreign-language adults in Ireland and Sweden have very similar chances of performing at Level 2 or 3 in the domain – 20% and 18% respectively – but the chances of native-born, native-language adults in the two countries performing at those levels are very different – 25% and 49%, respectively.

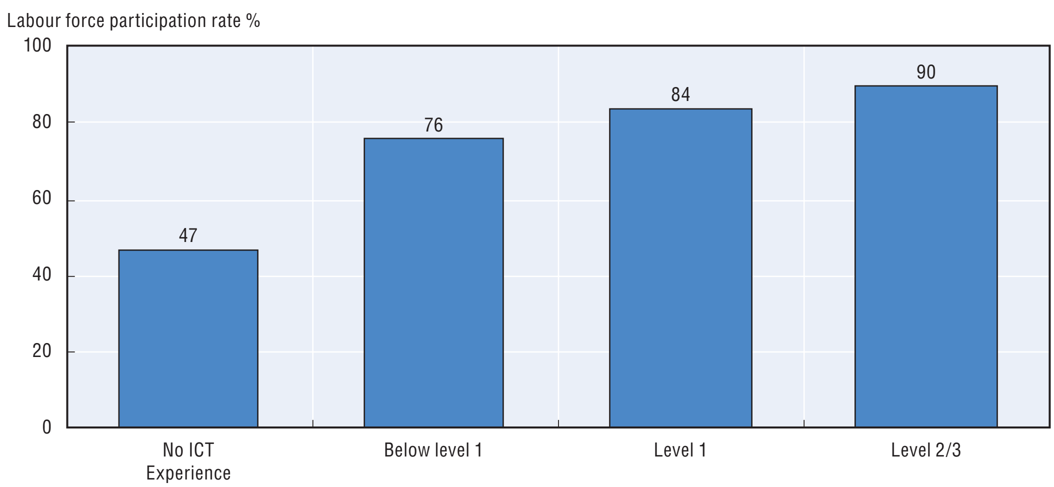
Returns on digital skills among adults

In economies and societies transformed by the multiple and often disruptive impacts of digitalisation it is no surprise that having digital skills matters for one's prospects in life. First, the returns are clear on employability and participation in labour markets.

In all countries, the labour force participation rate is lowest among adults with no experience in using ICT: only 47% of these adults participate in the labour force (Figure 2.11). By comparison, the participation rate was 90% among adults who performed at the highest levels of proficiency (Level 2 or 3) in using digital devices to solve problems and 76% among adults with very low proficiency (below Level 1).

Figure 2.11. **Labour force participation, by problem-solving proficiency using ICT**

Adults aged 25-65, OECD average



OECD (2015c), "Does having digital skills really pay off?", Adult Skills in Focus, No. 1, OECD Publishing, Paris. DOI: *http://dx.doi.org/10.1787/5js023r0wj9v-en*.

This difference in labour force participation rates could possibly be the result of some other factors related to the use of ICT, such as having a higher level of education or using digital applications regularly at home. But even after accounting for adults' age, gender, level of education, proficiency in literacy and numeracy, and use of e-mail at home, there is a 6 percentage point difference in labour force participation rates between adults with the highest levels of skills in problem solving using ICT and those who are proficient at the lowest level, while the difference in labour force participation rates between the latter group and those with no experience in using ICT is 15 percentage points. This suggests that proficiency in problem solving using ICT, in itself, has a positive impact on labour force participation, regardless of all the other factors considered, including literacy skills.

The labour force advantage associated with more proficiency in solving problems using ICT is greatest in England/Northern Ireland (United Kingdom), Ireland, the Netherlands and Norway. In England/Northern Ireland (United Kingdom) and Ireland, the rate of labour force participation among adults performing at Level 2 or 3 on the survey is 17 percentage points higher than among adults performing at or below Level 1, after accounting for other factors. In Norway, the difference in labour force participation rates between the two groups is 11 percentage points.

The disadvantage associated with having no experience at all in using ICT is even greater in many countries. In England/Northern Ireland (United Kingdom), the labour force participation rate among adults with no ICT experience is 33 percentage points lower than that of adults who performed at the lowest level in problem solving, even after taking various socio-demographic characteristics into account. This difference is also large in the United States (31 percentage points) and Australia (28 percentage points).

A related benefit is the wage premium associated with higher digital skills. Workers who have no experience in using ICT earn 18% less per hour, on average, than those who perform below Level 1 in the survey. Even after taking other factors into account, such as age, gender, educational attainment, proficiency in literacy and numeracy, and use of e-mail at work, adults with no experience in using ICT earn on average 6% less per hour than those who perform at even the lowest level of proficiency.

Workers who are proficient at Level 2 or 3 in problem solving using ICT earn 26% more per hour than those performing below Level 1. However, in these cases, the higher wages largely reflect other factors, such as workers' educational attainment, proficiency in literacy and numeracy, and the use of e-mail at work. When comparing workers with similar socio-demographic characteristics, levels of proficiency in literacy and numeracy, and frequency of e-mail use at work, the wage advantage between the two groups shrinks to 4% and disappears altogether if other factors, such as the type of occupation and the frequency of reading, writing and using numeracy skills on the job, are also taken into account. In other words, workers with better skills in problem solving in digital environments are paid more because they also tend to have better cognitive skills, in general, and because they work in jobs that involve greater use of information-processing skills.

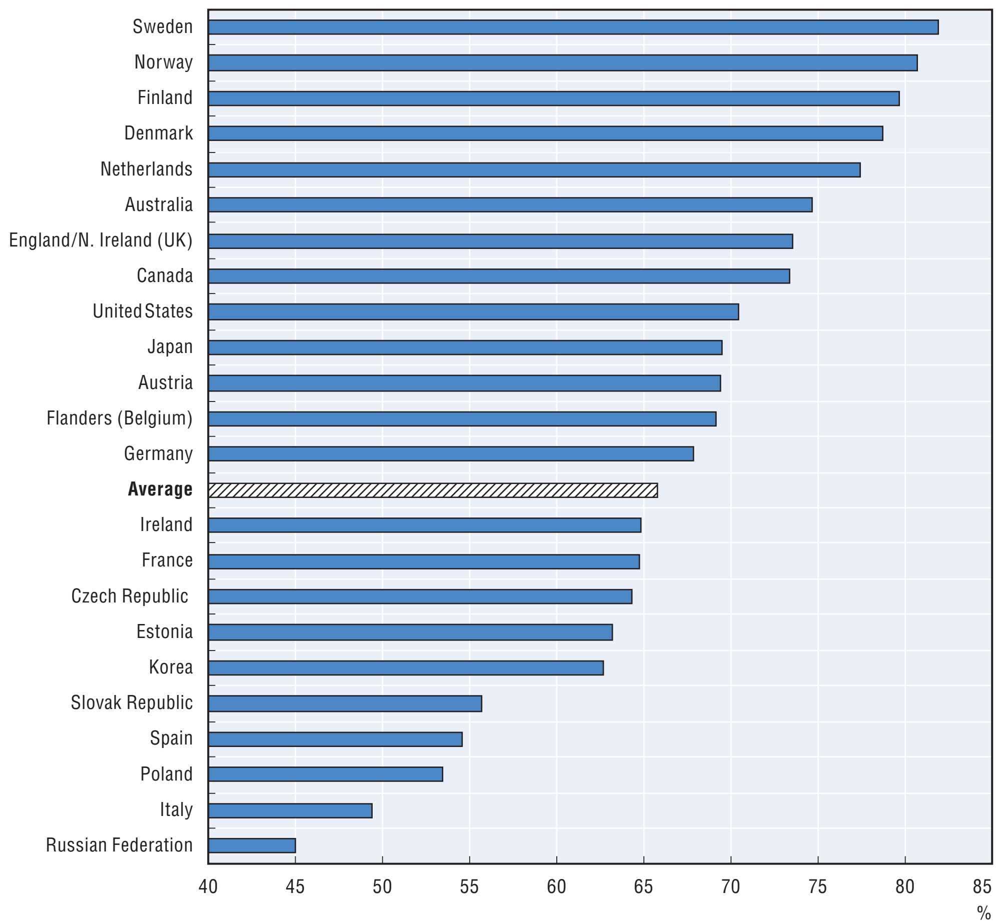
The importance of using ICT in the workplace is illustrated by the fact that the average salary per hour for workers who use e-mail regularly at work is significantly higher than that of workers who use e-mail less frequently. Workers who use e-mail frequently in their jobs earn 9% more per hour, on average, than those who are equally proficient in literacy, numeracy and problem solving, but who use e-mail infrequently. Thus, simply having acquired ICT skills is not enough; those skills must be used in the workplace if they are to make a difference in wages.

However, as Figure 2.12 shows, the use of ICT at work seems to vary a great deal across countries. In Nordic countries, around 80% adults use a computer at work while the figure is only around 55% of adults or less in Italy, Poland, the Russian Federation, the Slovak Republic and Spain.

Further analysis of the labour market outcomes of digital skills shows that skills and readiness to use ICT for problem solving leads to substantially higher returns even for individuals with low levels of formal qualifications (Lane & Conlon, 2016). There are many situations where individuals with low levels of formal schooling and relatively high skills in using ICT outperform individuals with higher levels of formal schooling but lower ICT skills. This phenomenon is particularly striking in the United States, England/

Northern Ireland (UK), Poland, Estonia and Japan. More generally, across the OECD, there is a 10-12 percentage point return on having minimal ICT skills compared to no skills or lack of readiness to use ICT skills, irrespective of the level of formal education. In other words, skills and readiness to use ICT for problem solving often entirely compensate for low levels of formal education in the labour market. The high labour market rewards associated with skills and readiness in using ICT is in part independent of the level of schooling achieved.

Figure 2.12. **Percentage of workers who use a computer at work**

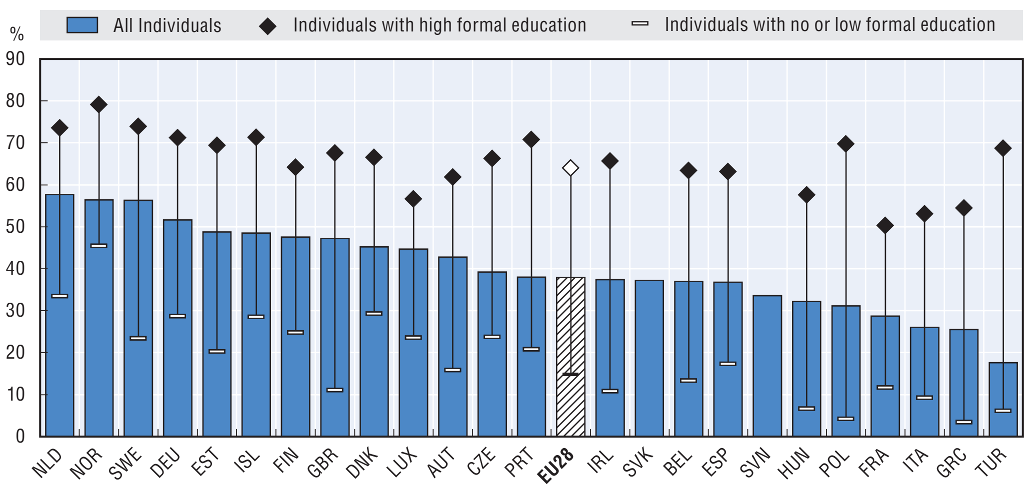


Source: OECD (2015a), "Does having digital skills really pay off?", *Adult Skills in Focus*, No. 1, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/5js023r0wj9v-en.

Another piece of research using the PIAAC database also concludes that better ICT skills are systematically related to higher wages: a one-standard-deviation increase in ICT skills leads to an almost 8% increase in wages in the international analysis and to an increase of 15% in the German analysis (Falck, Heimisch and Wiederhold, 2016). Placebo tests showing that the variables which exogenously determine Internet access cannot explain any variation in numeracy or literacy skills suggest that it is possible to insulate the wage effect of ICT skills from that of general ability. Digital skills seem to result in significant benefits in employment and earnings in their own right.

Job mobility is an important driver of knowledge transfer and spillover effects, which in turn foster innovation and growth in the digital economy. However, in 2013 only 39% of individuals in the EU labour force judged their computer skills to be sufficient to look for a job or change job within a year. Between countries, this percentage varied between 60% in the Netherlands and 25% in Greece. In all countries, individuals with a higher level of formal education report higher confidence in their computer skills, compared to those with no or low formal education. The gap between these two groups exceeds 60 percentage points in Poland and Turkey (Figure 2.13).

Figure 2.13. **Percentage of individuals who judge their computer skills would be sufficient if they were to apply for a new job within a year, 2013**



Source: OECD computations based on Eurostat, Information Society Statistics, May 2014.

StatLink http://dx.doi.org/10.1787/888933148354

Fostering digital skills

Empowering individuals with the relevant skills for the digital world is key to enabling them to fully participate in their country's economic, social and cultural life now and in the future. The evolving nature of the digital economy requires individuals to rapidly adjust to shifts in demand for skills and changes in technology. Combined with good foundation skills and social and emotional skills, digital literacy is essential for inclusion in the digital economy and society.

In many OECD countries, responsibility for the promotion of digital literacy falls primarily to national education ministries, which determine the extent to which ICT skills are included in the curriculum. Broader national digital strategies may result in the introduction of ICT into schools, as in the case of Sweden and more recently Spain. National digital strategies may take a different approach in engaging young people with ICTs, such as the *Informatik-Biber* competition in Germany (see below).

In Sweden, education for ICT is integrated into curricula as a learning outcome: "every pupil, on completing primary and lower secondary school, must be able to use modern technology as a tool for knowledge-seeking, communication, creation and learning". The 2011

Schools Act introduced new/revised syllabuses and a new curriculum for Swedish primary and lower secondary schools. Upper secondary education has also acquired new syllabuses, and a new qualification descriptor has been introduced for teacher and pre-school teacher training programmes. The latest initiative, ICT for Everyone: A Digital Agenda for Sweden in 2011 reiterated that "Everyone of working age must have good digital skills to be employable or be able to start up and run businesses"(Empirica, 2014).

In the United States the Obama administration has recently launched the Computer Science for All Initiative to give all students across the country the chance to learn computer science (CS) in school. The initiative will provide USD 4 billion in funding for states, and USD 100 million directly for districts in the forthcoming budget. It will increase access to CS at all levels of school education by training teachers, expanding access to high-quality instructional materials and building effective regional partnerships. The initiative will also be supported by the private sector through new philanthropic investments of more than USD 60 million from companies such as Google, Microsoft, Oracle and Salesforce.org. Last but not least, the initiative also recognises that students must be equipped with strong computational thinking skills and the ability to solve complex problems.

In Germany, the national digital agenda, Digital Germany 2015, aims to promote ICT studies and career opportunities through the organisation of nationwide ICT and engineering related competitions. A notable example of this policy includes the yearly organisation of a national computer science contest for school children called *Informatik-Biber* (2014). The competition is aimed at students in grades 5-13 (aged 10 to 15-16) and has been held annually in November since 2007. It is funded by the German Federal Ministry of Education and Research. It seeks to increase young students' interest in computer science, without requiring prior knowledge. In 2013 a total of 206 430 students took part in the competition (IVI and Empirica, 2014).

Some OECD countries have implemented a number of policies to promote digital literacy and inclusion for specific groups of the population who may lag behind (such as older people and women) to ensure that access and use of digital technologies benefits all segments of the population equally. Norway (Box 2.5) and Portugal offer examples of good practice in this area.

In Portugal, under the National Strategy for Digital Inclusion and Literacy, the ICT and Society Network promotes digital inclusion and literacy of the population at large. This network is a multi-stakeholder national platform with more than 500 members that mobilises regions, cities, municipalities, companies, government, academia, private sector, non-governmental organisations, the media, educators and citizens, in a proactive participation in reducing the share of the population that has never used the Internet.

The European Commission has been at the forefront of policy initiatives to address ICT-related skills. In 2007, the Communication E-Skills for the 21st Century set the basis for its policy response to the growing demand for highly skilled ICT practitioners and to achieve digital literacy for all citizens (European Commission, 2007).

Box 2.5. **The National Programme for Digital Inclusion in Norway**

Internet access and use in Norway is among the highest across OECD countries. According to the Norwegian Media Barometer 2015, 87% of those aged between 9 and 79 use the Internet during the course of a day. Daily Internet use is highest (99%) among 16-24 year-olds, compared with 52% of those aged 67-79. According to the national statistics, weekly Internet use among 67-79 year-olds has increased from 52% in 2010 to 62% in 2013. This suggests that many older Norwegians are keeping up with modern digital life and see the advantages of using new digital tools.

With these encouraging statistics Norway recently launched a more ambitious two year national programme which aims at significantly reducing the number of citizens who are not familiar with digital technologies regardless of age, gender, education, residence and participation in the workforce.

The programme is run by the Ministry of Local Government and Modernisation and enjoys the collaboration of big players in the ICT industry. Thus far the programme has developed web-based resources for educators and trainers in digital competence. The programme arranges collaborative regional conferences across the country, to ensure close collaboration and the sharing of resources between regional and national contributors. In addition, it is developing a magazine to inspire elderly non-digital citizens to get involved in the digital world. Different grants are being established to help develop local and regional educational initiatives. Plans are also on their way to develop national indicators of digital competence and digital inclusion.

Sources: Note from the Ministry of Local Government and Modernisation Department for national ICT policy and Public sector reform (2016); OECD (2016b), "Skills for a digital world: 2016 Ministerial Meeting on the Digital Economy background report", *http://dx.doi.org/10.1787/5jlwz83z3wnw-en*.

The Communication was followed by the institution of a broader EU e-skills strategy which is producing a number of positive outcomes in the area of ICT skills development. The Competitiveness and Innovation Framework Programme (CIP) financed the initiatives stemming from the implementation of the e-skills strategy, while the initiatives for 2014-20 focus on SMEs under the umbrella of the programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME). The EU plans future actions to address the critical need for e-leadership skills focusing on the promotion of professionalism among ICT practitioners and the creation of a larger talent pool of entrepreneurs, business leaders, managers and advanced users with a focus on the strategic use of new information and communication technologies (European Commission, 2016).

Current initiatives include the Opening-up Education initiative to modernise education for the digital age and the e-Skills for Jobs awareness-raising campaign about ICT professional jobs. The Grand Coalition for Digital Jobs is a cross-European multi-stakeholder partnership that facilitates collaboration among businesses, education providers, and public and private actors to reduce skills gaps by increasing the number of training programmes and making the most of the job opportunities offered by digitisation in Europe. So far, this initiative has been successful in attracting around 60 stakeholder pledges offering training, apprenticeships and placements and carrying out awareness-raising activities to encourage young people to study and pursue careers in ICT. It has also raised political awareness and support for these issues. Thirteen member states have set up national coalitions and more are planned. Some states have also produced digital skills strategies.

The EU e-skills strategy has undergone a number of evaluations to monitor progress by each member state. In the period 2009-13 the action focused on three pillars: digital literacy, professionalism for ICT practitioners and e-leadership. The largest number of activities was registered in the cluster around professionalism for ICT practitioners (Empirica, 2014). In contrast, activities related to e-leadership, including support for the acquisition of digital leadership skills among entrepreneurs, were less common.

Digital skills among 15-year-old students

What about the digital skills in the school-age population? The PISA 2012 survey has included computer-based tests that allow to asses digital reading skills and navigation behaviour of 15-year-old students (Box 2.6).

Box 2.6. **Testing students' digital reading skills and navigation behaviour in PISA 2012**

The PISA 2012 survey included assessments of how well 15-year-old students are able to read, navigate and understand online texts, with 32 countries and economies participating in the test of reading and mathematics on computers. A simulated browser environment, with websites, tabs and hyperlinks, provided a controlled setting in which students' reading performance, and also their browsing behaviour, could be observed. A key feature of digital reading tasks is that they use the typical text formats encountered on line; as a result, many of them require students to navigate through and across texts by using such tools as hyperlinks, browser buttons or scrolling, in order to access the information. Demands for general knowledge and skills related to computers were kept to a minimum. They included using a keyboard and mouse, and knowing common conventions, such as arrows to move forward. A short introduction to the test provided all students with the opportunity to practise using the tools through which they could interact with the test items, as well as response formats.

To describe the navigation behaviour of students in the digital reading test, students' complete browsing sequences were divided into elementary sequences ("steps"), with an origin and a destination page. Two indices were derived from step counts. The first measured the quantity of navigation steps. To make this comparable across students who took different forms of the test, the index of overall browsing activity is computed as a percentile rank based on the distribution of all students who were administered the same questions. A student with a value of 73 on this index can be said to have browsed more pages than 73% of the students who took the same test.

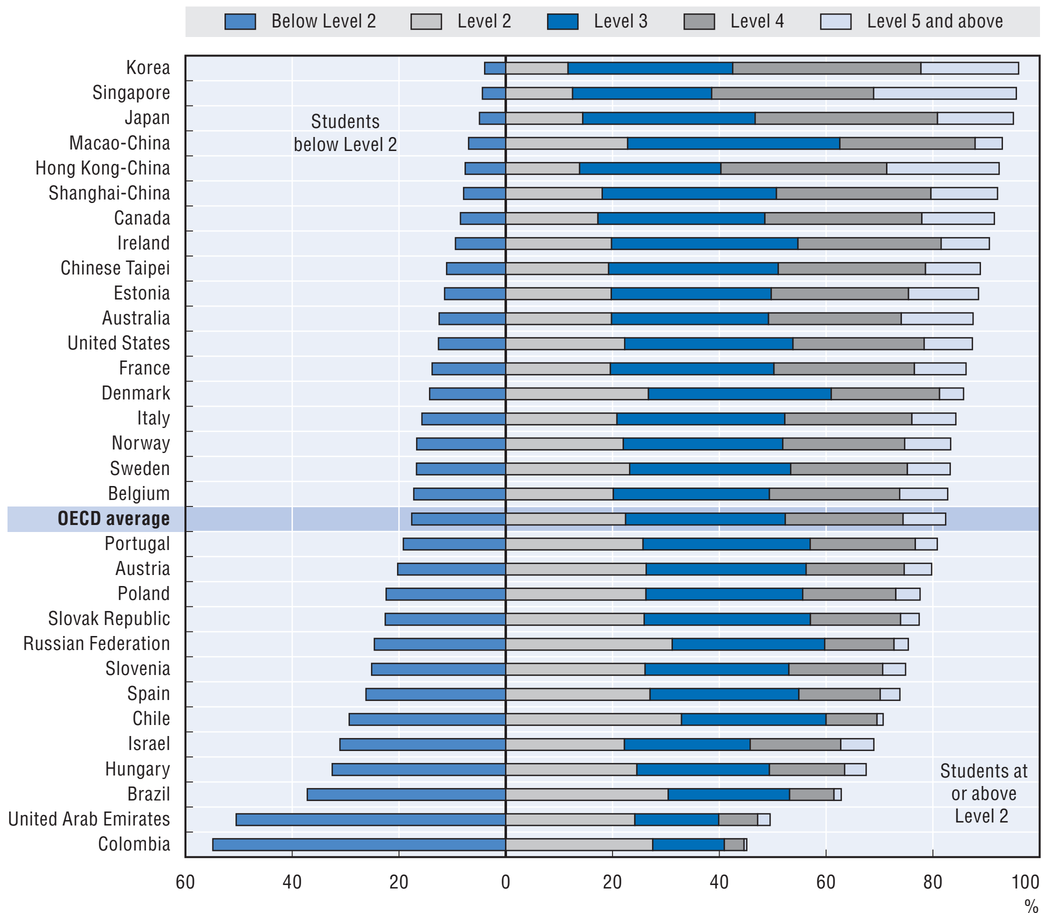
The second index related to the quality of the navigation steps taken. Not all of the pages available for browsing in the digital reading tests led students to information that was helpful or necessary for the specific task in hand. The index of task-oriented browsing measured how well students' navigation sequences conformed to expectations, given the demands of the task. High values on this index corresponded to long navigation sequences containing a high number of task-relevant steps (from a relevant page to another relevant page) and few or no missteps or task-irrelevant steps (steps leading to non-relevant pages).

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

As shown in Figure 2.14, the top-performing countries/economies in the PISA assessment of online reading were Canada; Hong Kong, China; Japan; Korea; Shanghai, China and Singapore. To a large extent, this ranking mirrors print-reading performance, confirming that it is not possible for students to excel in online reading without also being able to understand and draw correct inferences from printed texts. But there are important differences between the two rankings, and they are mainly related to a skill that is unique to digital reading: students' ability to navigate on line.

Figure 2.14. **Proficiency in digital reading**

Percentage of students at each level of digital reading proficiency



Countries and economies are ranked in descending order of the percentage of students at or above Level 2 in digital reading.

Source: OECD, PISA 2012 Database, Table 3.3.

StatLink http://dx.doi.org/10.1787/888933252935

Students in Korea and Singapore, for instance, perform significantly better in the digital medium than students in other countries with similar performance in print reading. So do students in Australia; Canada; Hong Kong, China; Japan and the United States, among others. In contrast, students in Poland and Shanghai, China – both strong performers in print reading – have greater difficulty in transferring their print-reading skills to an online environment.

Students proficient at Level 5 or above are skilled online readers. Top performers in digital reading are able to evaluate information from several sources, assessing the credibility and utility of what they read using criteria that they have generated themselves. They are also able to solve tasks that require the reader to locate information, related to an unfamiliar context, in the presence of ambiguity and without explicit directions. In short, they are able to navigate autonomously and efficiently. Critical evaluation and expertise in locating relevant information are the key skills in online reading, given the virtually unlimited number of texts that can be accessed on line, and the variation in their credibility and trustworthiness.

Students performing at Level 5 or above are able to deal with more technical material as well as with more popular and idiomatic texts. They notice fine distinctions in the detail of the text, allowing them to draw inferences and form plausible hypotheses.

Across the 23 OECD countries that participated in the digital reading assessment in 2012, 8% of students performed at this level and can be considered top performers in digital reading. In Singapore, more than one in four students (27%) perform at Level 5 or above. So do about one in five students in Hong Kong, China (21%) and Korea (18%).

At the lower end of the scale, students performing below Level 2 are able to complete only the easiest digital reading tasks in the PISA 2012 assessment, if any. They have difficulties using conventional navigation tools and features, and locating links or information that are not prominently placed. Some of these students can scroll and navigate across web pages, and can locate simple pieces of information in a short text, if given explicit directions. These students are referred to as low performers in digital reading because they perform at levels that are not likely to allow them full access to the education, employment and social opportunities afforded by digital devices.

On average, 18% of students are considered low performers in digital reading, across the 23 participating OECD countries. In partner countries Colombia and the United Arab Emirates, more than half of all 15-year-old students perform at this low level. Large proportions of low-performing students are also found in Brazil (37%), Hungary (32%), Israel (31%), Chile (29%) and Spain (26%). In contrast, less than 5% of students perform below Level 2 in Japan, Korea and Singapore. These countries are close to ensuring that all students have the basic knowledge and skills required to access and use information that can be found on the Internet.

Navigating digital information

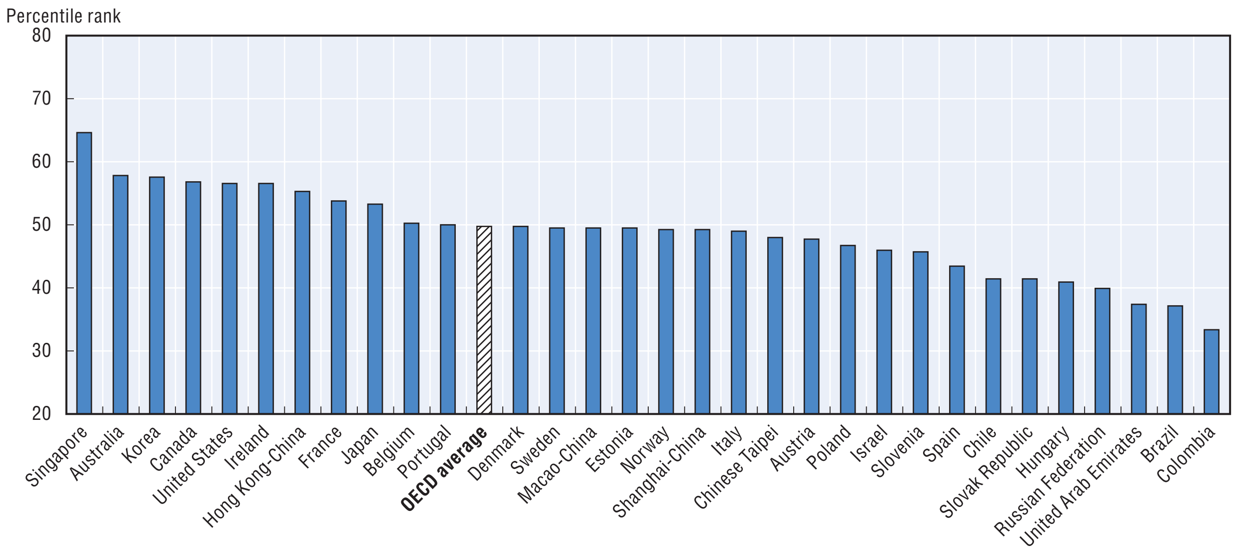
But there's more to digital reading than deciphering and comprehending text. Why are students in some countries/economies – notably Australia; Canada; Hong Kong, China; Japan; Korea; Singapore and the United States, among others – far better at reading digital texts than students in other countries/economies who score similarly in the print-reading test? The PISA findings show it is because they know how to navigate their way through and across digital texts.

An analysis of students' navigation behaviour in the digital reading test sheds light on what lies behind these countries' comparative edge in digital reading among students. Figure 2.15 shows that, on average, students in Singapore, followed by students in Australia, Korea, Canada, the United States and Ireland, rank the highest for the average quality of their browsing. Students in these countries tend to be the most selective when navigating on line. They carefully assess which links to follow before clicking on them, and follow relevant links for as long as is needed to solve the task. As a result, in all of these countries, performance in digital reading is better than would be expected based solely on print-reading performance.

Students in East Asian countries/economies have the longest navigation sequences of all when they browse through the pages of the digital reading assessment. In Hong Kong, China; Japan; Korea and Singapore, these sequences are generally of good quality too. But in Macau, China; Shanghai, China and Chinese Taipei, as many as one in five students visits more task-irrelevant pages than task-relevant ones. These students may be persistent in their efforts, but they are digitally adrift.

Figure 2.15. **Task-oriented browsing**

Average rank of students in the international comparison of students taking the same test form



Note: The *index of task-oriented browsing* varies from 0 to 100. High values on this index reflect long navigation sequences that contain a high number of task-relevant steps and few or no missteps or task-irrelevant steps.

Countries and economies are ranked in descending order of the index of task-oriented browsing activity.

Source: OECD, PISA 2012 Database, Table 4.1.

StatLink http://dx.doi.org/10.1787/888933253082

One in ten students in OECD countries had only limited or no web-browsing activity, signalling a lack of basic computer skills, a lack of familiarity with web browsing or a lack of motivation. There are very few such students in East Asian countries/economies. In contrast, in Brazil, Colombia, Hungary, Israel, Poland and the United Arab Emirates, more than one in six students belong to this group and contribute to these countries' lower-than-expected performance in digital reading.

In sum, the browsing sequences of students in Australia, Canada, Korea, Singapore and the United States are, on average, the most task driven, and thus better quality. Students in East Asian countries and economies tend to have long navigation sequences but deviate from the expected path more often than in other countries. One possible reason for this is that in these countries and economies, even the students who are most likely to make mistakes are willing to try. In the confined space of a simulated web environment, this behaviour occasionally leads them to the right cues to solve PISA tasks. It may have more negative consequences if applied to the unconfined World Wide Web.

Bridging the new digital divide

Across all the domains assessed by PISA, socio-economic status has a strong influence on the performance of students. As discussed above, disadvantaged students in some countries still have limited access to ICT devices or less experience in using them. How does the strength of the relationship between the PISA index of economic, social and cultural status (ESCS) and performance vary across computer- and paper-based assessments? What does this imply for the relationship between digital skills and familiarity with computers and their uses?

In the assessment of digital reading, differences in the PISA ESCS index account for 12% of the variation in performance on average across OECD countries, slightly less than in print reading (13%). Differences in reading proficiency across socio-economic groups only partially account for differences in performance in digital reading. There is a small, direct association between socio-economic status and digital reading performance. This direct association most likely stems from differences in navigation and evaluation skills – i.e. those components of reading that are emphasised to a greater extent when reading on line than when reading print. Even in digital reading, however, this direct association accounts for only 0.5% of the variation in performance, while the indirect association (through the effect of socio-economic status on print-reading skills) accounts for 11.5% of the variation.

By analysing how the relationship between digital reading performance and socio-economic status has evolved over time, it is possible to assess whether the bridging of the so-called first digital divide – the fact that access to ICT is now almost universal – has also translated into a reduction of the second digital divide – the fact that socio-economic status still has an impact on how well students can use new tools. In Belgium, Colombia and Poland, socio-economic status had a strong impact on performance in digital reading in 2009. In these three countries and in Sweden, however, the relationship had weakened considerably by 2012 even though none of these countries showed a similar trend for print reading. Meanwhile, in all four countries where equity in digital reading performance had improved between 2009 and 2012, equity in access to ICT at home had also improved. This suggests that greater equity in digital reading was mostly achieved by reducing the specific impact of socio-economic status on digital skills, rather than the general impact of socio-economic status on reading performance.

Key messages for innovation policies in education

It is easy to feel overwhelmed by the changes that digital technology has brought to our daily lives. Access to the Internet, increasingly through mobile devices, has a profound impact on the way we collect information, communicate with others, perform daily tasks and professional tasks, enjoy ourselves, and learn. Educational attainment and digital skills profoundly affect our capacity to use and benefit from digital technologies. Indeed, experience using digital technology and digital skills greatly enhance employment, wages and other social outcomes. Equipping individuals with the relevant skills to engage with the digital world – on top of good foundation skills such as reading and writing – will be key to their successful participation in economic, social and cultural life. Without both digital reading and navigation skills – implying metacognitive regulation – individuals find themselves digitally adrift.

It is difficult to imagine innovation strategies in education without a strong focus on developing digital skills among students and learners. Countries will need to invest in the acquisition of digital skills, and especially in reducing the skills gap and the inequalities among those benefiting from digital technologies, if they are to harness the potential of the digital world.

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Innovating Education and Educating for Innovation
The Power of Digital Technologies and Skills

Chapter 3

Digital technologies in education

Education policies need to reflect the fact that computers and the Internet are increasingly ubiquitous in everyday lives. This chapter considers the potential and actual impact of information and communications technology (ICT) on teaching and learning. It finds that between 2003 and 2012, students across the world have gained greater access to computers at school, although the intensity and variety of use varies across countries. It examines the factors which encourage teachers to make more use of ICT in the classroom and what holds them back, and looks at teachers' ICT problem-solving skills in relation to their peers outside education. Finally, it considers whether investment in technology, or students' use of computers and the Internet, are related to improved educational outcomes.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Integrating ICT in teaching and learning in schools

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

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

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

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

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

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

Quality of schools' educational resources including ICT

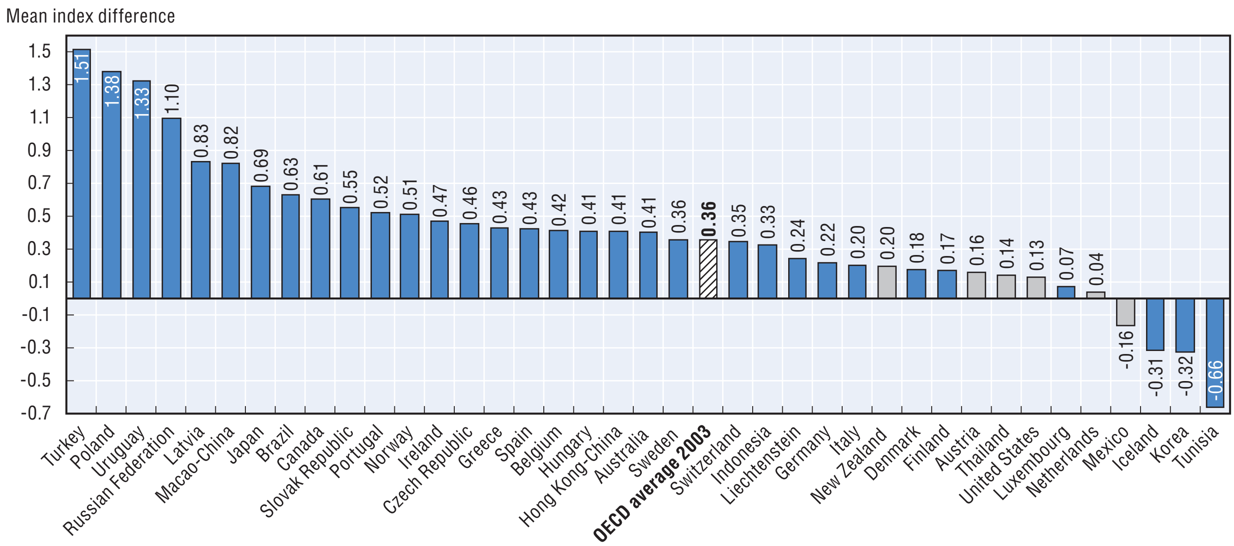
In 2012, the OECD Programme for International Student Assessment (PISA) asked school principals to report whether their school's capacity to provide instruction was hindered by a shortage or inadequacy of science laboratory equipment, instructional materials such as textbooks, computers for instruction, computer software for instruction and library materials. The responses were combined to create an index of quality of schools' educational resources that has a mean of 0 and a standard deviation of 1 in OECD countries. Positive values reflect principals' perceptions that a shortage of educational resources is hindering learning less than the OECD average, and negative values indicate that school principals believe the shortage hinders learning to a greater extent.

In 2012, on average, less than 10% of 15-year-old students across OECD countries attended schools whose principals reported that the school's capacity to provide instruction was greatly hindered by a shortage or inadequacy of educational resources. For example, only 9% of students were in schools whose principals reported that instruction was hindered a lot by a shortage of computers for instruction, and only 5% were in schools whose principals reported that instruction was hindered by a shortage of computer software. More globally, a shortage of computers for instruction hinders learning to a greater extent in Brazil, Greece, Iceland, Indonesia, Mexico, Sweden, Tunisia and Turkey: at least 15% of students attended schools whose principals reported that the school's capacity to provide instruction was hindered a lot by a shortage of computers. By contrast, principals are the most positive in Australia; the Czech Republic; France; Hong Kong, China; Hungary; Italy; Korea; Macau, China and the Slovak Republic, with more than 96% reporting that instruction in their school is not hindered by a shortage of computers.

Moreover, schools seem to be better equipped with new technology in 2012 than in 2003. Students in 2012 were less likely than their counterparts in 2003 to attend schools whose principal reported that instruction was hindered by a lack of computers and computer software. In 26 of the 38 countries and economies with comparable data, fewer school principals reported that their school's capacity to provide instruction was hindered by a shortage of computers in 2012 than in 2003 (Figure 3.1).

Figure 3.1. **Change in the index of quality of schools' educational resources, 2003 and 2012**

(e.g. textbooks, computers for instruction, computer software)



Notes: The index of quality of school educational resources was derived from the items measuring school principals' perceptions of potential factors hindering instruction at their school (SC14, from the PISA 2012 school questionnaire). Higher values on this index indicate better quality of educational resources in 2012. Dark blue bars indicate differences that are statistically significant. For comparability over time, PISA 2003 values on the index of quality of schools' educational resources have been rescaled to the PISA 2012 scale of the index.

Countries are ranked in descending order of the change between 2003 and 2012 in the index of quality of schools' educational resources.

Source: OECD (2015), *Education at a Glance: OECD Indicators*, Table D8.2. See Annex 3 for notes (*www.oecd.org/edu/eag.htm*).

StatLink http://dx.doi.org/10.1787/888933284698

Given that students' use of ICT for learning partly depends on the extent to which they have access to a computer, one key indication of access to ICT resources is the number of students per school computer. Across OECD countries, virtually all students attend schools with at least one computer. The number of students per computer is based on principals' reports about the number of students in the national modal grade for 15-year-olds, and on the number of computers available for these students. On average across OECD countries in 2012, there were five students for every school computer. Brazil, Costa Rica, Indonesia, Mexico and Turkey had the largest numbers (at least 15) of students per computer, while Australia; the Czech Republic; Macau, China; New Zealand; Norway; the Slovak Republic; the United Kingdom and the United States had fewer than two students per school computer.

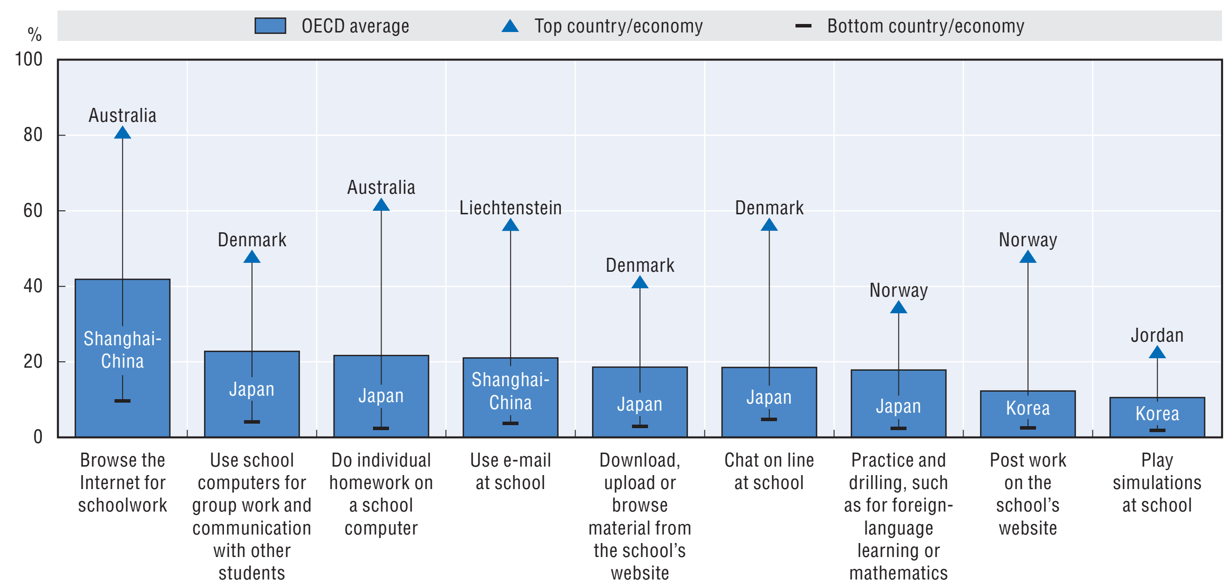
According to principals' reports, the number of 15-year-old students per school computer has not changed significantly across OECD countries between 2009 and 2012. Globally, the number of students per school computer decreased significantly in 12 of the 49 countries/economies with comparable data, and increased in only five – most notably in Turkey (from 12 to 45). The change in Turkey may have been partly the result of an increase in the student population during this period rather than a reduction in the number of computers available to them.

Students' use of computers at school

A basic indicator of the integration of ICT devices into teaching and learning is the share of students who use computers at school, particularly if this use is regular and occurs at least once a week. In PISA 2012, as in PISA 2009, students reported whether they use computers at school, and how frequently they engaged in nine activities using computers at school: 1) online chat; 2) using e-mail; 3) browsing the Internet for schoolwork; 4) downloading, uploading or browsing material from the school's website; 5) posting work on the school's website; 6) playing simulations at school; 7) practising and repeating lessons, for example when learning a foreign language or mathematics; 8) doing individual homework on a school computer; and 9) using school computers for group work and to communicate with other students. On average across OECD countries, 72% of students reported using desktop, laptop or tablet computers at school, compared to 93% reporting that they use computers at home. As in 2009, the most frequently performed task on school computers was browsing the Internet for schoolwork, with 42% of students on average doing so at least once a week. The least frequent activity was playing simulations at school, with just 11% of students on average across OECD countries (Figure 3.2).

Figure 3.2. **Use of ICT at school**

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



Source: OECD, PISA 2012 Database, Table 2.1.

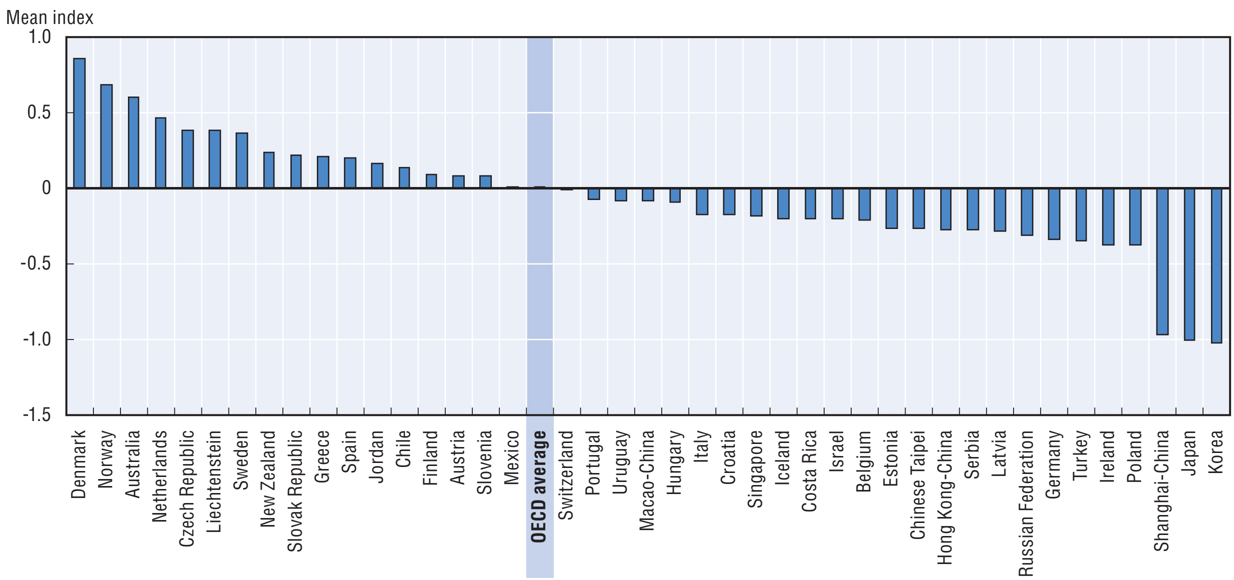
StatLink http://dx.doi.org/10.1787/888933252687

When all nine activities are combined into an index of ICT use at school, the countries with the highest mean values are Australia, Denmark, the Netherlands and Norway. In contrast, students in Japan; Korea and Shanghai, China make significantly less use of computers at school than students in any other country/economy, according to students' reports (Figure 3.3).

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

Increases in the intensity of computer use may be related to improvements in the quality of schools' ICT infrastructure, such as the introduction of mobile computers. When students can access computers in their classrooms instead of only in separate computer labs or at the school library, this could make a big difference in teachers' willingness to use computers in their teaching. Laptop and tablet computers offer much greater flexibility than desktop computers, and PISA data show that more and more schools have opted for these mobile computing solutions.

Figure 3.3. **Index of ICT use at school**



Countries and economies are ranked in descending order of the mean index of ICT use at school.
Source: OECD, PISA 2012 Database, Table 2.2.

StatLink http://dx.doi.org/10.1787/888933252700

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

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

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

Teachers and ICT

Teaching practices

The teaching practices deployed by teachers can play a significant role in how much students learn. Technology alone will not enhance learning, but using it as part of good teaching practice can open new doors to learners and teachers. It is striking that although technology is prevalent in our daily lives, the majority of teachers in many countries do not frequently use ICT in their practice. In some schools this may be due to the lack of provision, but teachers' professional development and their beliefs about work are key to unlocking technology's potential for teaching and learning.

The OECD Teaching and Learning International Survey (TALIS) was conducted in 2013 (Box 3.1). It asked lower secondary school teachers to choose a particular class from their teaching schedule and then respond to a series of questions about the frequency with which they used a number of teaching practices in this class. On average, of the eight practices considered, the two that teachers reported using most frequently were presenting a summary of recently learned content and checking students' exercise books or homework (around 80% of teachers, on average, reported using these practices).

Box 3.1. **What is TALIS?**

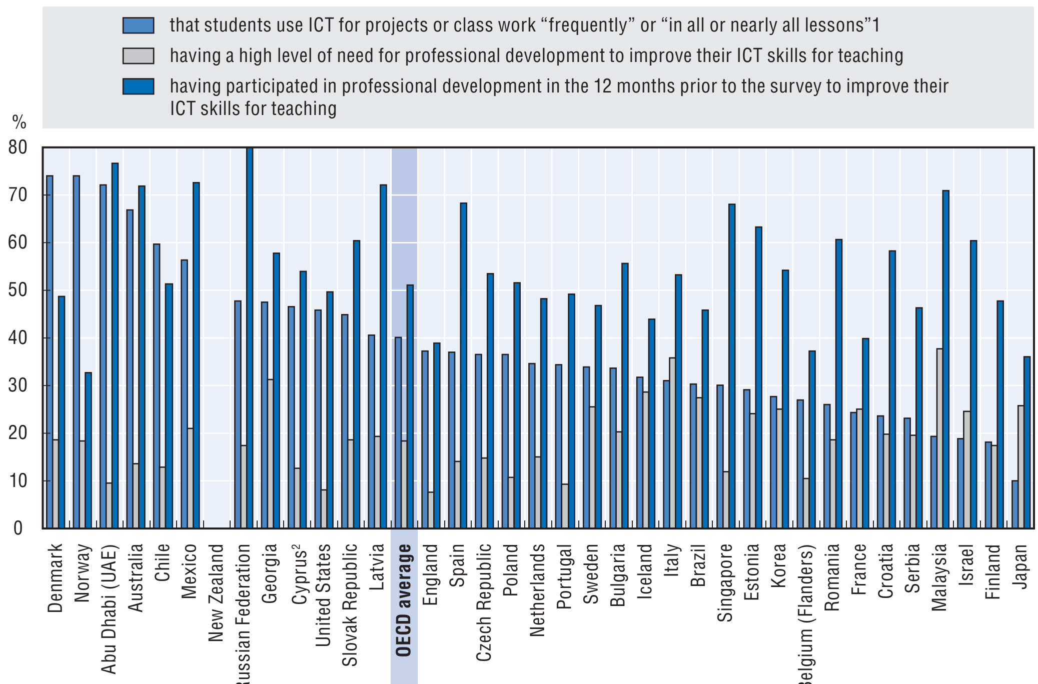
The Teaching and Learning International Survey (TALIS) is the first international survey examining teaching and learning environments in schools. It asks teachers and school principals about their work, their schools and their classrooms. This cross-country analysis helps countries identify others facing similar challenges and learn about their policies. TALIS 2013 focused on lower secondary education teachers and their principals. It sampled 200 schools in more than 30 countries and 20 teachers in each school.

More information is available at "TALIS – The OECD Teaching and Learning International Survey", OECD website, *www.oecd.org/talis*.

In contrast, only 40% of lower secondary teachers reported that students use ICT for projects or class work "frequently" or "in all or nearly all lessons". However, this average masks large disparities among countries. For example, in Australia, Chile, Denmark, Mexico, New Zealand, Norway and Abu Dhabi (the United Arab Emirates), more than half of teachers reported that students use ICT "frequently" or "in all or nearly all lessons", while fewer than one-quarter of teachers reported this in Croatia; Finland; France; Israel; Japan; Malaysia; Serbia and Shanghai, China (Figure 3.4).

Despite an increasing number of new initiatives to develop ICT skills for teaching (see Box 3.2 for two examples), and greater investments in new technologies, these figures show that teachers are still not systematically using ICT tools in their teaching. This may be because, among other things, teachers feel they are not sufficiently skilled in using ICT themselves. The PISA study found that, according to students' reports, those teachers who were more inclined to use and better prepared for student-oriented teaching practices such as group work, individualised learning and project work, are more likely to use digital resources. When asked to rank their professional development needs, 18% of teachers across all the countries and economies that participated in TALIS in 2013 cited teaching with ICT, second only to teaching students with special needs, followed by using new technologies in the workplace (16% of teachers, on average). Even larger proportions of teachers cited the need for professional development in teaching with ICT and using new technologies in the workplace in Brazil (27% and 37% respectively), Georgia (31% and 39%), Italy (36% and 32%) and Malaysia (38% and 31%). Providing further support to encourage teachers to use ICT tools in their teaching should therefore be a priority, whether through professional development or initial teacher training.

Figure 3.4. **ICT and teachers: teaching practices, teachers' need for professional development and participation in professional development activities (TALIS 2013)**



1. These data are reported by teachers and refer to a randomly chosen class they currently teach from their weekly timetable.

2. Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Countries are ranked in descending order, based on the overall percentage of teachers who report that students use ICT for projects or class work "frequently" or "in all or nearly all lessons".

Source: OECD (2015), *Education at a Glance: OECD Indicators*, Table D8.4. See Annex 3 for notes (*www.oecd.org/edu/eag.htm*).

StatLink http://dx.doi.org/10.1787/888933284717

There are several factors associated with increased use of ICT in teaching. For example, teachers should also be encouraged and given the time to collaborate with their colleagues. TALIS found that teachers who reported participating in professional development activities involving collaborative research, observation visits to other schools, or a network of teachers are more likely to have reported that they use teaching practices that involve small groups of students and ICT. In addition, teachers who report a positive disciplinary classroom climate are more likely to use ICT in their teaching. This could be because a positive classroom climate is more conducive to the use of ICT (e.g. because there are fewer disruptive students) or that the use of ICT helps to ameliorate classroom climate (e.g. because students enjoy interacting with technology). Teachers who hold constructivist beliefs about their job

– i.e. those who see themselves as facilitators of students' own inquiry, or see thinking and reasoning as more important than specific curriculum content – are also more likely to use ICT and other active teaching techniques. This may be due to the fact that ICT can enable students to pursue knowledge in more independent ways than traditional teaching, in line with the constructivist approach.

Box 3.2. **Promoting teachers' digital skills**

INDIRE (the National board for educational research and teacher development) formerly known as ANSAS develops content for teachers' professional development with the aim of stimulating innovation in teaching and learning, of bridging the distinction between formal, non-formal and informal learning environments, and, in a lifelong learning perspective, of reducing the distance between pedagogical practices and everyday life .

INDIRE has a rich resource bank for professional development related to the use of ICT in schools, including over 1 400 text or multimedia resources (including over 10 hours of video tutorials), many of which introduce subject-specific uses of ICT. Training is often in blended (face-to-face and online) mode, combining preparatory face-to-face sessions with online activities and materials that are specific to subjects and grade levels but also linked to curricular contents and distance tutoring.

From academic year 2012/13, INDIRE enriched its training offer with the new DIDATEC training. DIDATEC supports teachers to integrate ICT into their subject teaching, and will be initially offered at basic and advanced level in four southern regions (Campania, Calabria, Puglia and Sicilia). These regions are part of the *Programma Formativo Nazionale 2007-2013* supported by regional cohesion funds from the European Union. The aim of the DIDATEC training is to strengthen ICT skills among teachers to improve the quality of teaching and learning (ANSAS 2012).

Teaching workforce - mastering of ICT competences in France

Since 2010, France is looking to formalise ICT skills training for all its teachers and training professionals via the creation of a certificate on the use of digital technologies and the Internet, the *Certificat et internet de l'enseignement supérieur de niveau 2 "enseignant"* (C2i2e).

The C2i2e certificate validates professional competences in the pedagogical use of basic numerical technologies and technology tools, which are today recognised as central to the exercise of their functions. The training leading to the acquisition of the C2i2e certificate is open to all people studying towards a degree in the teaching profession, as well as any postgraduate student (Bac +5) and already established teachers and trainers.

Some of the skills targeted include the use of digital tools for research purposes, to foster team work and encourage student networks, to improve pedagogical methods and ensure the effective evaluation and monitoring of students' ICT skills competences in school.

Obtaining the certificate is not a prerequisite to the successful completion of a teaching degree. However, the Ministry of Education expects that all teaching student candidates and graduated teachers will obtain the certificate within three years of graduating, thus ensuring its future teaching workforce has mastered ICT

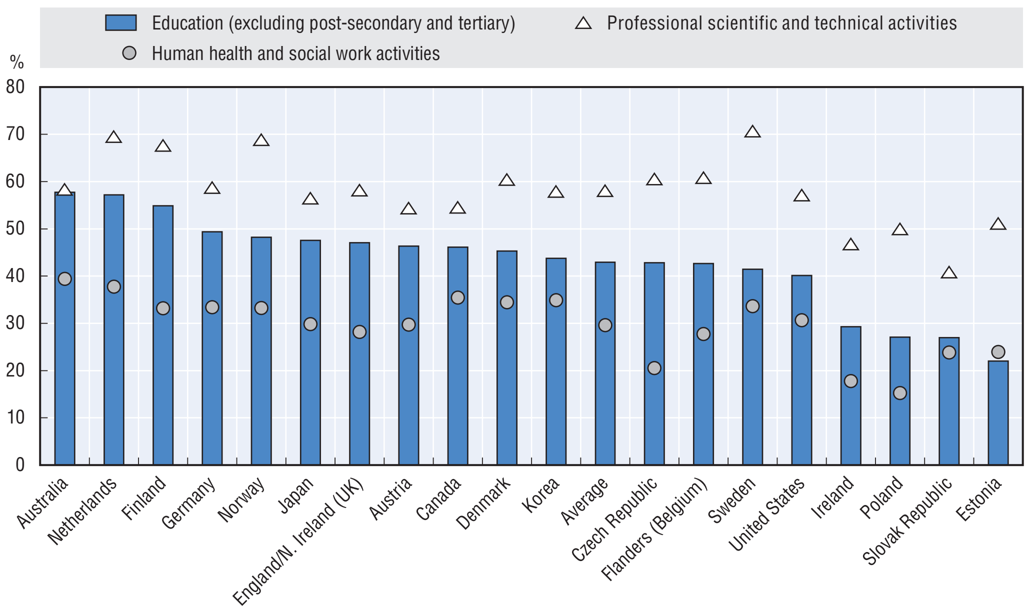
Sources: Avvisati, F. et al. (2013), "Review of the Italian strategy for digital schools", http://dx.doi.org/10.1787/5k487ntdbr44-en; Direction générale de l'enseignement supérieur et de l'insertion professionnelle (DGESIP), *https://c2i.education.fr/spip.php?article216*.

Teachers' ICT skills

Is teachers' use of ICT in teaching related to the ICT skills that teachers have? Data from the OECD Survey of Adult Skills data (see Box 2.4 in Chapter 2) can help estimate teachers' ability to use ICT for problem solving. As Figure 3.5 shows, workers employed in the education sector (as teachers or in other roles) are more likely to have good ICT and problem-solving skills than workers employed in human health and social work activities. The difference is 15 percentage points on average across the countries and sub-national entities participating in the Survey of Adult Skills (PIAAC) in 2012, and over 20 percentage points in the Czech Republic and in Finland.

Figure 3.5. **Percentage of teachers with good ICT problem-solving skills, compared with selected industries**

Survey of Adult Skills, 25-64 year-olds, 2012



OECD (2016), "Teachers' ICT and problem-solving skills: Competencies and needs", *Education Indicators in Focus*, No. 40, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jm0q1mvzqmq-en*

However, on average, workers in the education sector are 15 percentage points less likely to have good ICT and problem-solving skills than those working in the professional, scientific and technical activities sector, which includes scientific research and development and legal and accounting activities. Therefore, although education can be considered as a high-performing sector for ICT and problem solving, it still lags behind some very skill-intensive activities.

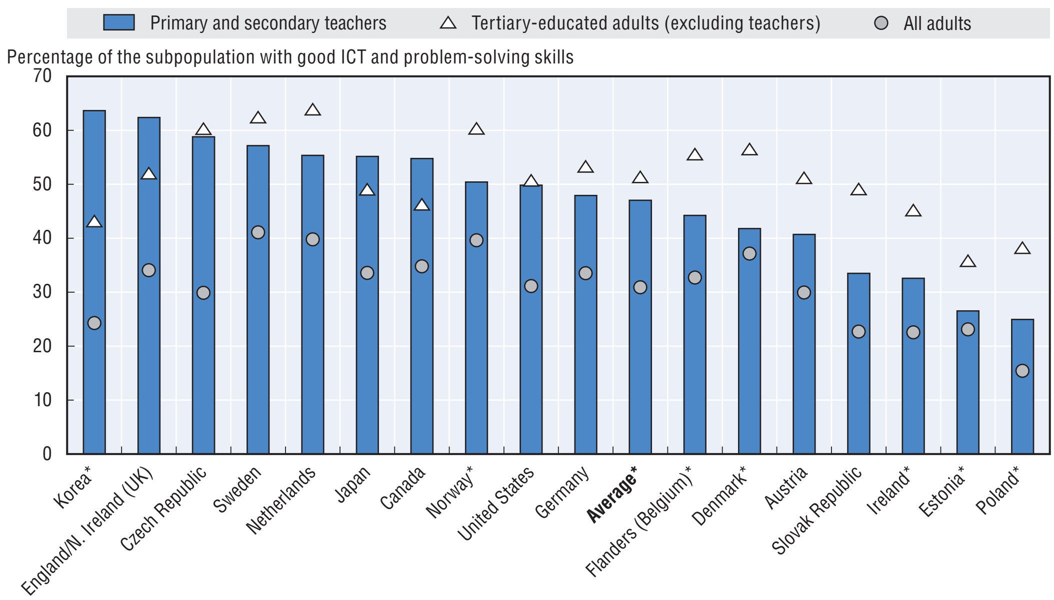
The fact that education has a relatively high proportion of workers with good ICT and problem-solving skills can be explained by the fact that it employs many tertiary-educated workers, particularly teachers. In all countries participating in the Survey of Adult Skills, the proportion of other tertiary-educated adults (i.e. excluding teachers) with good ICT and problem-solving skills is significantly higher than that of the general adult population (Figure 3.6) – on average, 51% compared to 31% for the adult population overall. The proportion of primary and secondary teachers with good skills in this domain is also much higher than that of the general population, although it is three percentage points lower than that of other tertiary-educated adults. In 13 out of the 17 countries for which data are available, primary and secondary teachers are less likely than other tertiary-educated adults to have good ICT and problem-solving skills. Teachers only outperform other tertiary-educated adults in Canada, England/Northern Ireland (United Kingdom), Japan and Korea.

This may be partially explained by the fact that younger people have better ICT and problem-solving skills than older people (OECD, 2013). When age is taken into account, primary and secondary teachers are four percentage points more likely than other tertiary-educated adults to have good problem-solving skills in a digital and ICT environment, and in Japan and Korea the difference is over 40 percentage points. In Korea, this could be due to the ability of schools to attract highly skilled professionals by offering relatively high wages to primary and secondary teachers compared to similarly educated workers (OECD, 2015a).

Another reason could be that teachers in these countries have better opportunities than other tertiary graduates to develop their skills on the job.

Figure 3.6. **ICT skills among primary and secondary teachers, other tertiary-educated adults and the overall adult population, 2012**

Percentage of individuals with good ICT and problem-solving skills among 25-64 year-olds, by population subgroup



OECD (2016), "Teachers' ICT and problem-solving skills: Competencies and needs", *Education Indicators in Focus*, No. 40, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jm0q1mvzqmq-en*

The age gradient in problem-solving and ICT skills is also good news: younger generations of teachers seem to be closing the skills gap. New generations of teachers who are better trained and who participate in professional development activities throughout their careers will probably be able to adopt innovative practices that are more suited to 21st century learning environments. Governments should not blame older teachers for having poor problem-solving and ICT skills but equally they cannot afford to miss the opportunity to fill teaching posts left vacant by retirees with younger, more tech-savvy problem solvers.

The effects of ICT on students' learning outcomes in PISA

Do improvements in learning environments, the availability of ICT in schools and the ICT skills of teachers result in better learning outcomes of students? Have the investments made paid off? A better understanding of how computers affect education outcomes is critical for effective investment in education technology. This section explores the relationship between computer access in schools, computer use in classrooms and performance in PISA assessments.

PISA allows relationships to be analysed between performance and computer access and use across countries/economies as well as within education systems, across students and schools. The strength of the PISA data lies in the wide range of contexts covered. However, non-experimental, cross-sectional data such as those gathered through PISA, do not allow even sophisticated statistical techniques to isolate cause-and-effect relationships between computer access and use of computers on the one hand, and performance on the other. Patterns of correlation can be identified, but these must be interpreted carefully, because several alternative explanations could be given for the same pattern.

Performance and availability of ICT resources

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

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

Figure 3.7, for instance, shows that, between 2003 and 2012, students' performance in mathematics deteriorated in most countries that had reduced their student-computer ratios over the same period (after accounting for differences in per capita GDP). One possibility is that such school resources were, in fact, not used for learning. But overall, even measures of ICT use in classrooms and schools often show negative associations with student performance. Average reading proficiency, for instance, is not higher in countries where students more frequently browse the Internet for schoolwork at school. In countries where it is more common for students to use the Internet at school for schoolwork, students' performance in reading declined, on average. Similarly, mathematics proficiency tends to be lower in countries/economies where a larger share of students use computers in mathematics lessons.

One possibility is that resources invested in equipping schools with digital technology may have benefitted learning outcomes other than in reading, mathematics and science, such as digital skills, of transitions into the labour market. However, even the associations between ICT access and use and digital reading or computer-based mathematics are weak, and sometimes negative. Even specific digital reading competencies do not appear to be higher in countries where browsing the Internet for schoolwork is more frequent.

Performance and use of ICT at school and at home

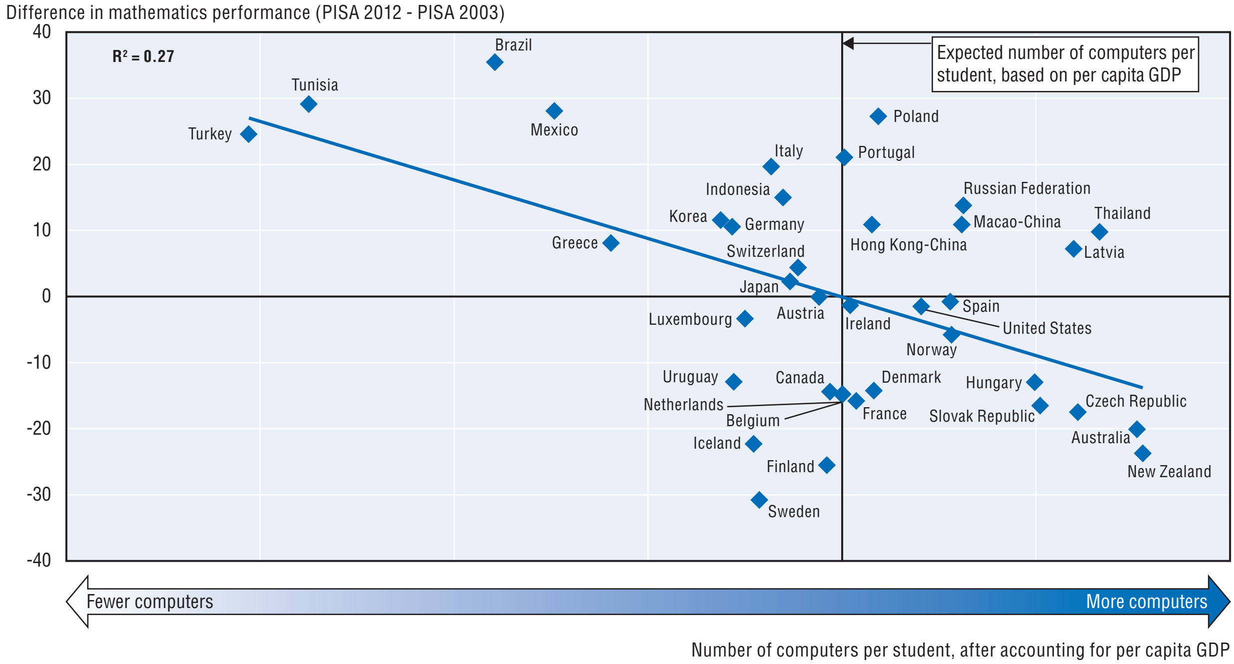
This section compares students within countries/economies, focusing particularly on performance in digital reading and computer-based mathematics, where, in theory, a stronger relationship with exposure to computers can be expected. Do students perform better in digital reading when they read on line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

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

Figure 3.8 (left panel) shows that students who make slightly below-average use of computers at school have the highest performance in digital reading. Overall, the relationship is graphically illustrated by a hill shape, which suggests that limited use of computers at school may be better than no use at all, but levels of computer use above the current OECD average are associated with significantly poorer results

Figure 3.7. **Trends in students' mathematics performance and number of computers at school (2012)**

All countries and economies



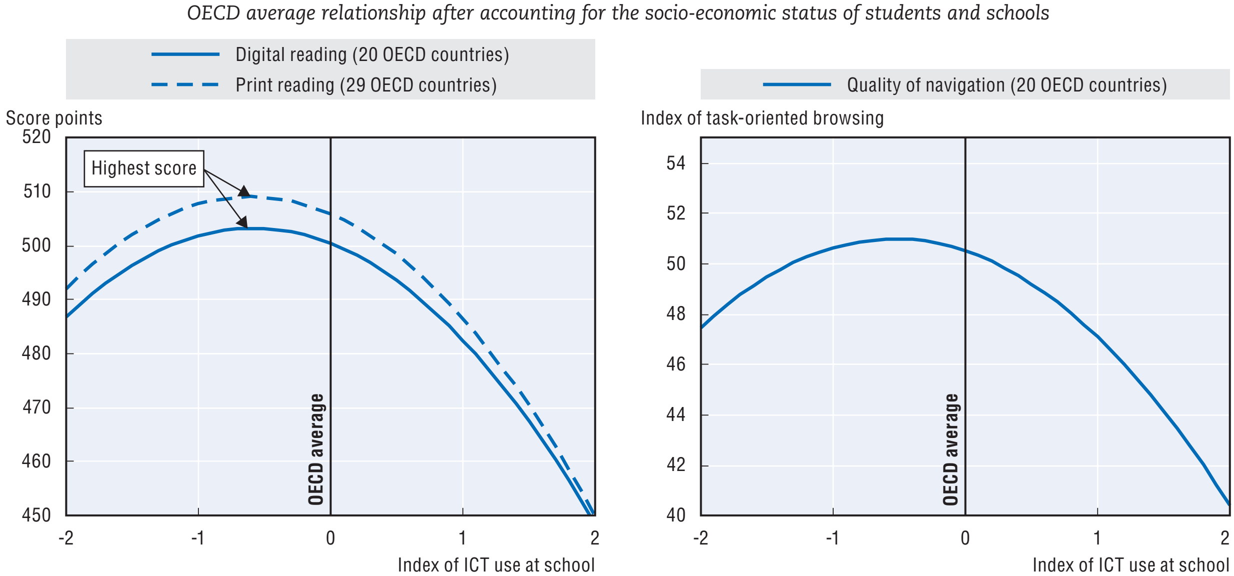
Note: The horizontal axis reports residuals from a regression of the student-computer ratio on per capita GDP (both variables are measured in logarithms).

Source: PISA 2012 Dataset, Table I.2.3b (OECD, 2014), Table IV.3.2 (OECD, 2013) and Table 2.11.

StatLink http://dx.doi.org/10.1787/888933253262

Figure 3.8. **Students' skills in reading, by ICT use at school**

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



Notes: The lines represent the predicted values of the respective outcome variable, at varying levels of the index of ICT use at school, for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero. Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the index of task-oriented browsing (see Chapter 4).

Source: OECD, PISA 2012 Database, Table 6.2.

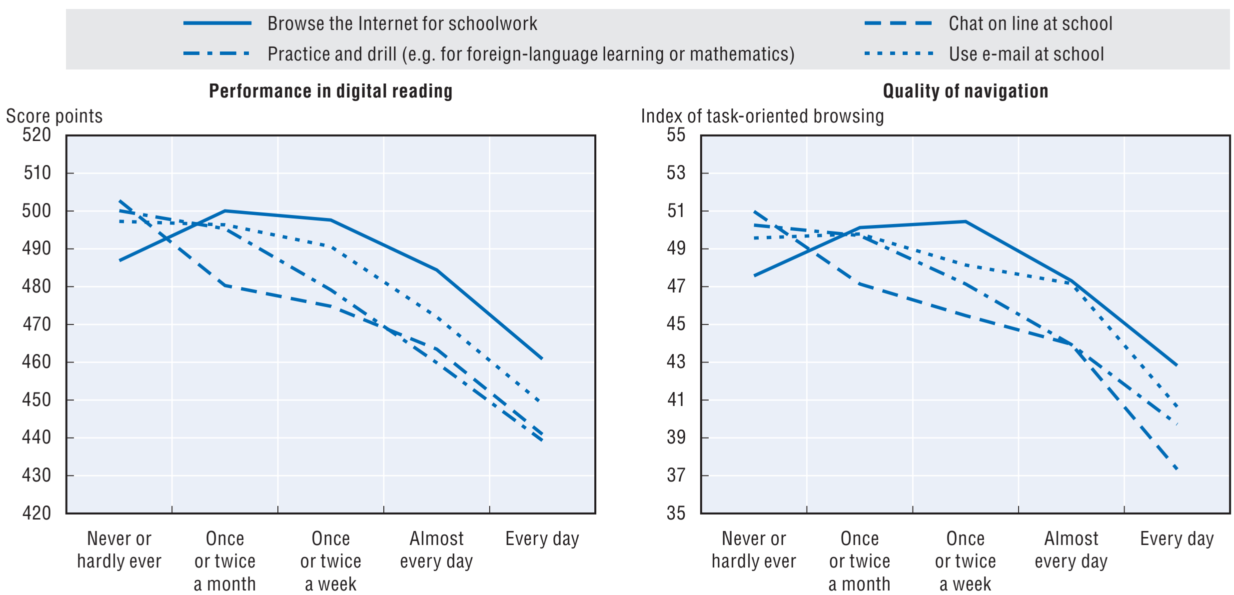
StatLink http://dx.doi.org/10.1787/888933253280

Figure 3.8 also shows a similar relationship between computer use and performance for both digital and print reading; this suggests that even specific online reading skills do not benefit from high levels of computer use at school. This is confirmed by the right-hand panel, which relates the index of task-oriented browsing – an indicator of students' navigation and evaluation skills in online texts (see Box 2.6 in Chapter 2 for more detail) – to the index of ICT use at school. Even such specific online reading skills do not appear to benefit from more intensive use of computers at school.

Thus, overall, using computers at school does not seem to confer a specific advantage in online reading. In detail, however, the relationship between performance and the frequency of different activities does vary (Figure 3.9).

Figure 3.9. **Frequency of computer use at school and digital reading skills**

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



Notes: The charts plot the predicted values of the respective outcome variables for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.

Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).

Source: OECD, PISA 2012 Database, Tables 6.3a, b, c and g.

StatLink http://dx.doi.org/10.1787/888933253296

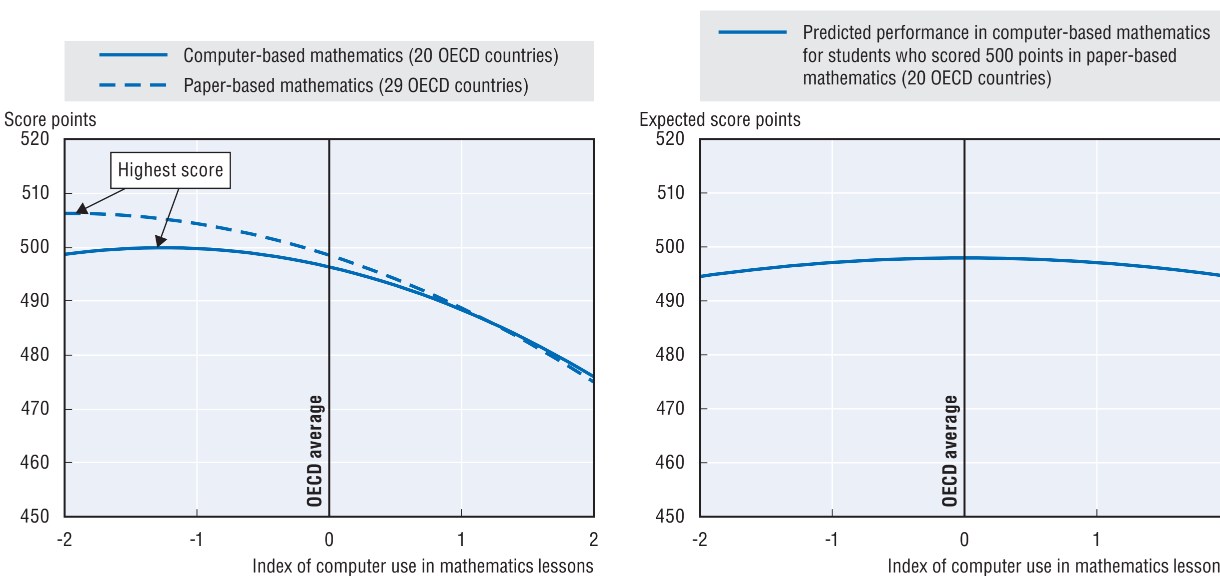
The decline in performance associated with greater frequency of certain activities, such as chatting on line at school and practising and drilling, is particularly large (Figure 3.9). Students who frequently engage in these activities may be missing out on other more effective learning activities. Students who never or only very rarely engage in these activities have the highest performance. In contrast, the relationship between browsing the Internet or using e-mail and reading skills only becomes negative when the frequency increases beyond once or twice a week. Thus, encouraging students to read on line, in moderation, may have positive effects on reading more generally. Teachers who offer a diverse range of materials to read can promote engagement with reading, particularly among boys. In 16 out of 25 countries/economies with available data, students who browse the Internet at school once or twice a month score above students who never do so on the PISA digital reading scale. In addition, the highest quality of navigation is attained by students who reported browsing the Internet at school "once or twice a week", suggesting that practice with online navigation in a school setting can be particularly important for specific skills related to online reading.

There are also significant differences between countries. In Australia, in particular, more frequent browsing of the Internet at school – even the most frequent browsing – is associated with gains in digital reading skills. Australia is among the countries where students use computers at school the most.

Similarly, across OECD countries, students who do not use computers in mathematics lessons tend to perform better in the paper-based and the computer-based assessment of mathematics (Figure 3.10). This may reflect, to a large extent, the fact that advanced mathematics classes rely less on computers than more applied mathematics classes. However, even the ability to use computers as a mathematical tool – a skill that is only assessed in the computer-based assessment of mathematics – appears to benefit little from greater use of computers in mathematics classes, as shown in the right panel of Figure 3.10.

Figure 3.10. **Performance in mathematics, by index of computer use in mathematics lessons**

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 computer use in mathematics lessons*, for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.

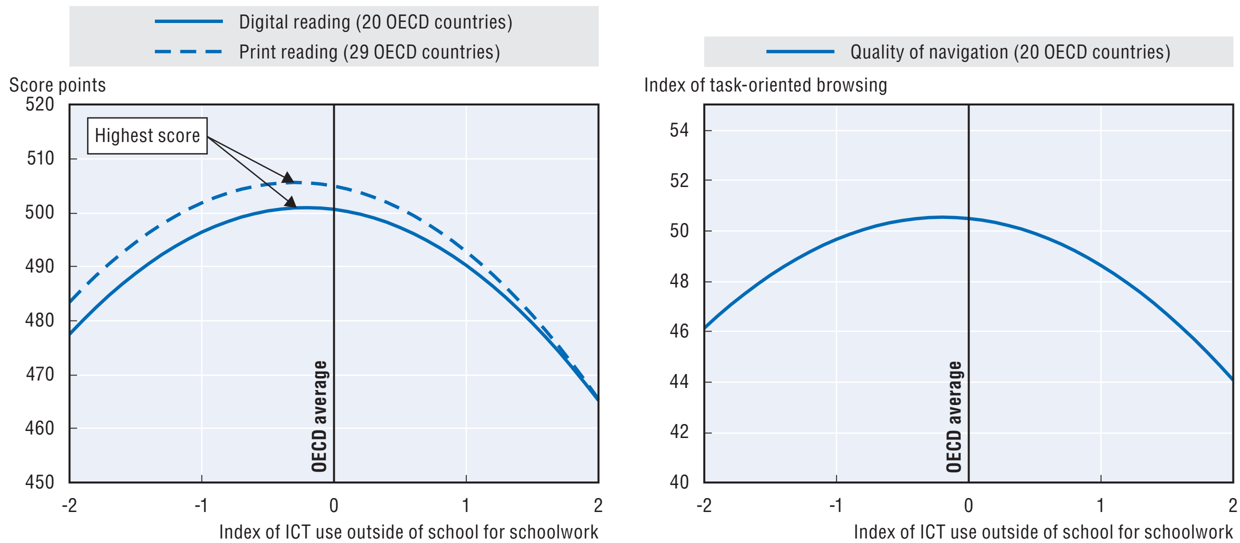
Source: OECD, PISA 2012 Database, Table 6.4.

StatLink http://dx.doi.org/10.1787/888933253302

The relationship between reading skills and using computers for schoolwork outside school is, at first glance, similar to the relationship between reading skills and using computers for schoolwork at school (Figure 3.11). The index of ICT use outside school for schoolwork measures how frequently students do homework on computers, browse the Internet for schoolwork, use e-mail for communications related to school, visit the school website, and/or upload or download materials on it. Higher values of this index correspond to more frequent and more varied uses.

Figure 3.11. **Students' skills in reading, by ICT use outside school for schoolwork**

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



Notes: The lines represent the predicted values of the respective outcome variable, at varying levels of the *index of ICT use outside of school for schoolwork, for students with a value of zero on the PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.

Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).

Source: OECD, PISA 2012 Database, Table 6.6.

StatLink http://dx.doi.org/10.1787/888933253329

Students who use computers for schoolwork outside school to a moderate degree perform best in both digital and print reading – higher than students who never use computers at all. When computer use increases beyond the OECD average, however, the relationship turns negative. This hill-shaped relationship is also observed when considering the quality of students' navigation using the index of task-oriented browsing (Figure 3.11, right hand chart).

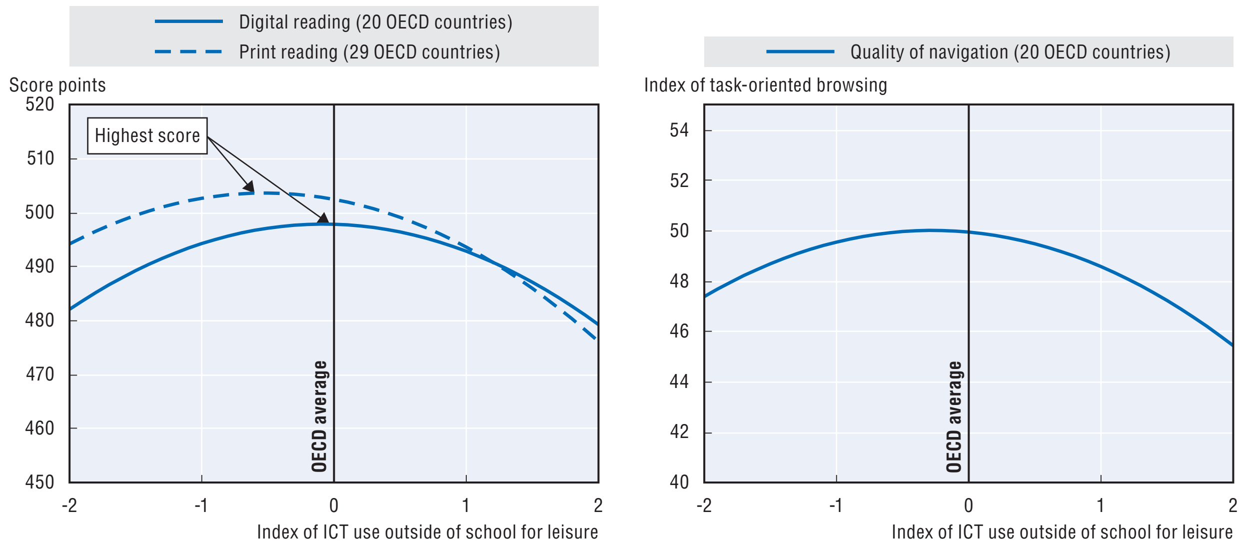
The two homework activities listed in the ICT familiarity questionnaire (doing homework on computers, and browsing the Internet for schoolwork) show a similar hill-shaped relationship with performance. Students who never do these activities on computers, and students who do them every day, are the two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

Finally, students also use computers at home for playing games, to remain in contact with friends, and for all sorts of leisure activities, such as downloading music, reading news, or simply browsing the Internet for fun. The frequency and variety of leisure activities in which students engage when using computers at home is summarised in an index of ICT use outside school for leisure.

Figure 3.12 shows the hill-shaped relationship between the uses of computers at home for leisure and digital reading performance. Once more, moderate users tend to perform better than both intensive users and rare users. The figure also shows a similar, hill-shaped relationship with print reading. In this latter case, however, rare users perform better than intensive users (those with the highest values on this index).

Figure 3.12. **Students' skills in reading, by ICT use outside school for leisure**

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



Notes: The lines represent the predicted values of the respective outcome variable, at varying levels of the *index of ICT use outside of school for leisure,* for students with a value of zero on the *PISA index of economic, social and cultural status* (ESCS), in schools where the average value of ESCS is zero.

Quality of navigation refers to students' ability to plan and regulate their navigation behaviour on line; this is measured by the *index of task-oriented browsing* (see Chapter 4).

Source: OECD, PISA 2012 Database, Table 6.8.

StatLink http://dx.doi.org/10.1787/888933253343

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

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

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

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

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

Other studies have assessed the impact of specific uses of ICT on education outcomes. Experimental evaluations of specific uses of computers for instructional purposes – such as educational software – tend to report positive results more often (Bulman and Fairlie, forthcoming). However, to interpret these findings it is crucial to determine whether the introduction of computer-assisted instruction increases learning time overall or displaces other learning activities.

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

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

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

Rigorous experimental evidence on the effect of home computer use on students' performance in school is more limited. Three recently published experiments report mixed evidence. Exploiting a sharp discontinuity in eligibility rules for a computer-vouchers programme for families with school-aged children in Romania, Malamud and Pop-Eleches (2011) found mixed evidence on impacts, with some outcomes, such as school grades, deteriorating for the eligible students, and other outcomes improving, such as computer skills and cognitive skills measured with Raven's progressive matrices. In a randomised trial in California, where free computers where given to students in grades 6-10 who previously had none, no effects were found on grades, test scores, credits earned or engagement with school (Fairlie and

Robinson, 2013). Finally, in a randomised trial in Peru, about 1 000 primary school children selected by a lottery received a free laptop computer for home use. Five months after receiving the computer, these children reported greater use of computers overall and were more proficient in using them than non-recipients. However, no effects were found on reading and mathematics scores, on cognitive skills, and on more general ICT proficiency while teachers reported that recipients of free computers exerted less effort at school compared to non-recipients (Beuermann et al., 2015).

Overall, the evidence from PISA, as well as from more rigorously designed evaluations, suggests that simply increasing access to computers for students, at home or at school, is unlikely to result in significant improvements in education outcomes. Furthermore, both PISA data and the research evidence concur on the finding that any positive effects of computer use are specific – limited to certain outcomes, and to certain uses of computers.

Key messages for innovation policies in education

The history of digital technologies in education so far has mainly been one of undelivered promises, naïve beliefs and ineffective policies. Recent evidence, including the analysis of PISA data reported in this chapter, shows that introducing digital technologies in schools has not resulted in the promised improved efficiency through better results at a lower cost. There is a weak or even negative association between the use of ICT in education, and performance in mathematics and reading, even after accounting for differences in national income and in the socio-economic status of students and schools.

Part of the explanation for this must lie with the dominant focus on technology and connectivity, both among suppliers of goods and services and among policy makers. Schools and education systems are not yet ready to realise the potential of technology and the appropriate conditions will need to be shaped if they are to become ready. Gaps in the digital skills of both teachers and students, difficulties in locating high-quality digital learning resources and software from among a plethora of poor-quality ones, a lack of clarity over learning goals, and insufficient pedagogical preparation on how to blend technology meaningfully into lessons and curricula, have driven a wedge between expectations and reality. If these challenges are not addressed as part of the technology plans of schools and governments, technology may do more harm than good to the teacher-student interactions that underpin deep conceptual understanding and higher-order thinking.

Despite the many challenges involved in integrating technology in teaching and learning, digital technology offers great opportunities for education. In many classrooms around the world technology is used to support quality teaching and student engagement, through collaborative workspaces, remote and virtual labs, or through the many ICT tools that help connect learning to authentic, real-life challenges. Teachers who use inquiry-based, project-based, problem-based or co-operative pedagogies often find new technology to be a valuable tool and industry is developing a number of technologies, such as learning analytics and serious games, that promise to exploit the rapid feedback loops afforded by computers to support real-time, formative assessments, thus contributing to more personalised learning.

What this shows is that the successful integration of technology in education is not so much a matter of choosing the right device, the right amount of time to spend with it, the best software or the right digital textbook. The key elements for success are the teachers, school leaders and other decision makers who have the vision, and the ability, to make the connection between students, computers and learning.

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Innovating Education and Educating for Innovation
The Power of Digital Technologies and Skills

Chapter 4

The potential of technology-supported learning

As Chapter 3 showed, simply introducing digital technology into education for technology's sake does not materially improve results. Such whole-system reforms need to place teaching practice rather than technology in the driving seat. This chapter explores how innovative approaches to technology-supported learning can truly enhance education. It considers five models of how teaching can be supported by technology: 1) educational gaming, 2) online laboratories, 3) technology-enabled collaboration, 4) real-time formative assessment and 5) technological support for skills-based curricula, using examples from the Hewlett Packard Catalyst Initiative project.

It then considers other means by which technology can improve learning, whether in schools or for individuals: e-learning, where the web is to support learning; open educational resources, which provide customisable materials for teachers and learners; and new forms of online education, such as massive open online courses which potentially make education available to anyone, anywhere, at any time.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Introduction

The sobering results from the analysis of PISA 2012 data outlined in Chapter 3 suggest that the introduction of digital technologies in education so far has been mainly driven by the wrong reasons – the mere availability of technology, and a strong push for "modernisation" and accountability. Nor has it been accompanied by appropriate strategies to improve pedagogy and teaching practices, the professional development of teachers, and the provision of excellent software and courseware.

When it comes to such whole-system reforms, many of the traditional reform instruments – accountability pressures, individual teacher approaches, technology without pedagogy and fragmented strategies – have been described as the "wrong drivers" because they do not lead to culture change (Fullan, 2011). Therefore, systems should be lead by the "right" drivers, i.e. a deliberate policy force that ends up achieving better measurable results for students. These include the focus on the learning-teaching-assessment nexus, social capital to build the profession, pedagogy matching technology and developing systemic synergies (OECD, 2013). These drivers work directly on changing the culture of teaching and learning. The glue that binds effective drivers together is the underlying attitude, philosophy and theory of action (Fullan, 2011: 5). The right drivers embed both ownership and engagement in reforms for students and teachers. The Italian approach to digitalising schools (Box 4.1) offers one example of the need to put pedagogy in the driver's seat to use technology effectively.

Box 4.1. **Digitalising schools in Italy**

The Italian National Plan for Digital Schools (*Piano Nazionale Scuola Digitale*) was launched by the Ministry of Education in 2007 to mainstream information and communications technology (ICT) in Italian classrooms and use technology to catalyse innovation in Italian education. The aim was that the plan would be conducive to new teaching practices, new models of school organisation, and new products and tools to support quality teaching. The plan was to equip Italian classrooms with ICT, namely interactive whiteboards.

However, by 2012, only 22% of classrooms were equipped with interactive whiteboards. At current rates, it would take over 10 years to equip 80% of Italian classrooms. The plan's small budget has limited the effectiveness of its diverse initiatives. Italy needed to speed up the process, offer more professional development for teachers to use technology in classrooms and provide greater funding for the National Plan. This case is a good example of focusing on pedagogic uses of technology and addressing the importance of professional development, but innovation has been hampered by budgetary constraints and delays in providing equipment. Nonetheless, it can serve as a front-runner to pilot and invent new learning environments, from which the Italian system can draw positive and negative lessons in the medium term.

Source: Avvisati et al. (2013), "Review of the Italian strategy for digital schools", *http://dx.doi.org/10.1787/5k487ntdbr44-en*.

How can technology-supported learning help to move beyond content delivery and truly enhance innovative education so that students develop a broad mix of skills? Could innovative teaching and learning approaches spark thinking and creativity, enhance student engagement, strengthen communication, and build collaboration? Would they make teaching and learning more effective, more relevant, and more enjoyable?

Questions such as these – and a desire to investigate new pedagogic models – led the OECD Centre for Educational Research and Innovation (CERI) to use the Hewlett Packard Catalyst Initiative as a case study (see Box 4.2). The Catalyst Initiative is an education grant programme initiated and supported by Hewlett Packard's (HP) Sustainability and Social Innovation team. Many education systems increasingly recognise the importance of developing students' skills and understanding for tomorrow's innovation societies. Catalyst projects explore how innovative pedagogic models supported by technology might help develop student skills and understanding within science, technology, engineering and mathematics (STEM) subjects. Moreover, the HP Catalyst Initiative is an excellent example of how partners from the industry can help to foster innovation in education. This chapter will discuss some innovative examples of successful technology-supported teaching and learning interventions, based on the OECD/CERI work on the HP Catalyst Initiative.

Educators should consider adopting these broad technology-supported pedagogic models to improve students' learning outcomes, including the development of higher-order thinking skills, and to expand the range of learning opportunities available to students. The challenge of adopting these models is more to do with integrating new types of instruction than overcoming technology barriers. Adoption also requires support from policy makers at a range of levels within education.

Box 4.2. **Design of the HP Catalyst Initiative**

The Catalyst Initiative financed a wide range of STEM+ education work by selected higher and secondary education institutions as well as non-governmental organisations (NGOs). In total, 50 organisations were full members – 30 joining in 2010 and another 20 since 2011. These individual projects were combined into six thematic consortia, each led by an additional "lead" organisation (Box 4.3). In addition, 29 organisations participated in the Catalyst Initiative network as non-funded associate members, also within the consortia. Hewlett Packard (HP) designed the six consortia and selected the leaders by invitation, then selected the full members through two competitive requests for proposals and with the support of a jury of experts. HP was looking for organisations that were thought-leading, credible and highly motivated, but the criteria for selecting the leaders were flexible with an emphasis on geographic balance. The eligibility criteria for full membership put a strong emphasis on the size of the applicant projects and their geographical spread. The additional guidelines highlighted a preference for projects that served disadvantaged students and were engaged in relevant networks through their previously funded work.

Since 2010, HP Sustainability and Social Innovation committed more than USD 10 million to the Catalyst Initiative work, to be carried out over a two year period. These resources were to a large extent directly allocated to the full members of the Initiative in in-kind and cash contributions, each receiving funding worth more than USD 158 000 in total. The in-kind part of the grant consisted mainly of technology such as tablet computers, servers and printers.

Catalyst members could also apply for competitive Innovation Fund and Leadership Fund cash awards – worth from USD 10 000 to USD 100 000 – aimed at accelerating collaboration and success of promising, scalable STEM+ education models. By the end of 2012, 7 partnerships, consisting of 21 organisations in total, had been awarded an Innovation Fund grant and 10 members a Leadership Fund grant. These funds were used mainly to collaboratively disseminate technology-supported education to more (diverse) student populations. The Catalyst Initiative also provided non-financial support for collaboration including opportunities for face-to-face meetings, online communication infrastructure, training and coaching, regular monitoring, feedback and communication.

Box 4.2. **Design of the HP Catalyst Initiative** *(cont.)*

This support was provided especially by the International Society for Technology in Education (ISTE) and the New Media Consortium (NMC). The structure of the Catalyst Initiative was designed to promote collaboration for innovation in STEM+ education at three different levels. First, at the project level, the 50 Catalyst members carried out core research and development work on technology and STEM+ education. Second, at the consortium level, full and associate members were grouped together to enhance collaboration and innovation around specific themes such as informal learning, assessment or teacher professional development (Box 4.3). Third, the Catalyst Initiative overall provided a wider umbrella and support framework for collaboration and mutual learning within and beyond the Initiative. For example, two face-to-face summits convening all projects – one in New Delhi, India, in 2011 and the other in Beijing, China, in 2012 – were planned from the start of the Initiative. The Initiative also set up an electronic platform to facilitate social networking, share information and materials and allow communication with others. Conference calls took place on a monthly basis between the consortia leaders and HP to support and exchange ideas on developments within the Initiative. HP also held monthly one-to-one discussions with each consortium leader, in addition to frequent e-mail contact.

A range of institutions who were leaders in their respective fields provided support for the Catalyst Initiative as Executive Advisors. The advisors included representatives from inter-governmental organisations such as the OECD. The Carnegie Corporation, C2k, the Consortium for School Networking, European Schoolnet, the Exploratorium, FutureLab, the Hewlett Foundation, ISTE, the National Science Resources Centre and the NMC also provided expertise for the Initiative.

See: HP Catalyst Initiative: *www8.hp.com/us/en/hp-information/social-innovation/catalyst.html*.

Source: Kärkkäinen, K. and S. Vincent-Lancrin (2013), "Sparking innovation in STEM education with technology and collaboration: A case study of the HP Catalyst Initiative", *http://dx.doi.org/10.1787/5k480sj9k442-en*.

Box 4.3. **The six HP Catalyst consortia**

Global Collaboratory

The Global Collaboratory consortium, created in 2010, promoted "transformation of STEM learning into an international project-based learning experience" by "bringing the world into the classroom and the classroom into the world". It explored themes of bridging cultures, languages and time zones as well as collaboration tools, models and barriers. The work built on possibilities provided by new technologies, particularly on grid computing network by the HP and UNESCO Brain Gain Initiative. The consortium was led by Meraka Institute, South Africa, and comprised seven full members from Egypt, Kenya, the United Kingdom and the United States, and five associate members.

Measuring Learning

The Measuring Learning consortium, created in 2010, concentrated on innovative approaches to assess STEM+ knowledge and skills, with a strong emphasis on real-time technology-based assessments. Specific attention was paid to measuring skills for thinking and creativity as well as social and behavioural skills. The consortium was led by Carnegie Mellon University in the United States, and comprised eight full members from seven countries: the People's Republic of China (hereafter China), France, India, Mexico, Russia, South Africa and the United States. It included seven associate members.

Box 4.3. **The six HP Catalyst consortia** *(cont.)*

Multi-Versity

The Multi-Versity consortium, created in 2010, focused on "understanding and disseminating effective practices" in online STEM education, in particular educational games, online laboratories, faculty development for online learning and models for online student interaction. The work built on the idea that, in the future, online education will become a central or even preferred way of learning especially in higher education, due to the increasing societal demand for more educated people. The consortium was led by Sloan Consortium, in the United States, and comprised eight full members from Brazil, Canada, China and the United States as well as eight associate members.

New Learner

The New Learner consortium, created in 2010, investigated learning how to learn and the creation of personal life-long learning networks that – with the help of technology – build on formal, non-formal and informal resources and people. The new learners of the future were envisaged to "have their own network of learning resources […] for continuous learning of STEM+ disciplines", as opposed to current undervaluation of non-formal and informal learning. The consortium was led by Agastya International Foundation, India, and comprised 11 full members and 4 associate members, making it the largest within the Catalyst Initiative. Its membership covered Brazil, India, South Africa, the United Kingdom and the United States.

Pedagogy 3.0

The Pedagogy 3.0 consortium, created in 2010, addressed innovations in teacher preparation to accommodate STEM+ learning in secondary schools, including the use of technology. The work built on the idea that "new and innovative approaches to teaching and learning aligned with new and developing technologies can be harnessed to increase and enhance learners' engagement in STEM+ subjects". The consortium was led by Futurelab in the United Kingdom, and comprised ten members and two associate members, making it the second largest within the Catalyst Initiative. Its membership covered seven countries: Australia, China, Germany, Kenya, Nigeria, the United Kingdom and the United States.

STEM-Preneur

STEM-Preneur is the most recent consortium, created in 2011 to address the possibilities of combining STEM and entrepreneurship education. At its heart lay an interdisciplinary learning experience for both technical and entrepreneurial minded students. The consortium was led by Tsinghua University School of Economics and Management in China, and comprised six full members and three associate members, making it the smallest within the Catalyst Initiative. The membership of the consortium covered Canada, France, India, Russia and the United States.

Source: Kärkkäinen, K. and S. Vincent-Lancrin (2013), "Sparking innovation in STEM education with technology and collaboration: A case study of the HP Catalyst Initiative", *http://dx.doi.org/10.1787/5k480sj9k442-en*.

Examples of technology-supported pedagogical models

Five noteworthy technology-supported pedagogic models emerged from the research carried out by grantees within the HP Catalyst Initiative. The five broad models are associated with gaming, virtual laboratories, international collaborative projects, real-time formative assessment and skills-based assessment.

Educational gaming

Educational gaming offers a promising model to enhance student learning in STEM education, not just improving content knowledge, but also motivation and thinking and creativity skills. Educators and policy makers should consider using it to enhance STEM learning outcomes and problem-solving skills and motivation. Designing games appears to lead to even deeper learning than just using them for educational purposes.

In educational gaming, students interact with video games, simulations or virtual worlds based on imaginary or real worlds, also seen as highly interactive virtual environments (Raju, Ahmed and Anumba, 2011; Shaffer, forthcoming; Aldrich, 2009). Educational gaming also includes collaborative project-based learning experiences where students themselves become game designers and content producers (Prensky, 2008; Jaurez et al., 2010; Raju, Ahmed and Anumba, 2011).

As a promising model for various disciplines and education levels, educational gaming may promote:

- **Learning by doing**. The interactive, reactive and often collaborative nature of educational gaming enable students to learn about complex topics by allowing them to (repeatedly) make mistakes and learn from them. Real-life based gaming allows experimentation that would otherwise be too costly or dangerous. Gaming can be particularly useful when educating professionals who need the capacity to think and work simultaneously, while relying on tacit knowledge such as architects, engineers, chemists, physicists, doctors, nurses, or carpenters (Raju, Ahmed and Anumba, 2011; Lin, Son and Rojas, 2011; Shaffer, forthcoming).
- **Student learning**. Educational gaming which covers specific topics or subject areas and takes place within a set of rules can increase students' achievements and subject-specific knowledge (Akinsola and Animasahun, 2007; Papastergiou, 2009; Yien et al. 2011; Bai et al., 2012; Shaffer, forthcoming). Constructing educational games seems to increase deep learning more than just using existing games (Vos, Meijden and Denessen, 2011).
- **Student engagement and motivation**. Being based on play and increasing challenges, educational gaming can foster student engagement and motivation in various subjects and education levels (Papastergiou, 2009; Annetta et al., 2009; Wastiau, Kearney and Van den Berghe, 2009; Lin, Son and Rojas, 2011; Yien et al., 2011; Yang, 2012; Shaffer, forthcoming). Low-achieving students may find the educational gaming experience more engaging than high-achieving students (Grimley et al., 2012). Students' motivation can increase more when they construct games themselves as opposed to just playing an existing game (Vos, Meijden and Denessen, 2011).
- **Students' thinking skills**. Games have the potential to help students find new ways around challenges, use knowledge in new ways and "think like a professional" (Shaffer, forthcoming). Educational gaming may also improve students' skills such as problem solving (Yang, 2012).

Two Catalyst projects illustrate the benefits of different kinds of educational gaming for various skills for innovation. The National University in the United States developed and validated a learning approach based on game design by higher education students (Box 4.4). The City Academy Norwich in the United Kingdom created a virtual world simulation to teach middle school students the intertwined relationships between energy demand, finance and the environment (Box 4.5).

Online laboratories

Online laboratories, whether remote or virtual, are another promising innovation intended to enhance technology-supported teaching and learning. Virtual online laboratories allow students to simulate scientific experiments while remote ones allow students to use real laboratory equipment from a distance through the Internet (Jona et al., 2011; Tasiopoulou and Schwarzenbacher, 2011).

Box 4.4. **The Game Design Methodologies (GDM) of National University, the United States**

The Game Design Methodologies (GDMs) of National University in the United States, base instruction on interactive and collaborative project-based approaches to video game design by students themselves. The GDM processes and principles were initially used in National University's "digital entertainment and interactive arts program, with the core objective of creating 'playcentric' video games" and later adapted to other courses such as engineering. In the GDM, students apply STEM content and principles in a systematic manner to build original video games using tablet computers. After the design phase, the games are played by student teams competing for the best gaming outcome relevant to the particular subject (Jaurez et al., 2010). The games produced by students are meant to be reusable for higher education.

Further implementation and testing suggest the GDM made a positive impact on various student learning outcomes from achievement to collaboration, engagement and creativity. Experimental research on 85 working adult students, on site and on line, studying one month economics courses at National University showed positive results. Playing games in the class benefited students in terms of understanding of "technical economics concepts directly related to the game", although it had "no effect on other subsequent subjects". The use of the GDM "increased final grades by as much as 5% vs. traditional scores" and the impact was particularly positive for females with "> 5 % increase vs. female performance in Economics". Moreover, the final grades of historical underperformers – those with below average grade point averages – increased ">10% vs. traditional underperformer scores". The GDM students were found to be engaged and satisfied as well as able to develop "writing, excel and presentation skills at a level" that they "otherwise would not achieve".

The GDM students were assigned "to create original games to describe specific concepts in principles of microeconomics courses" in 2011 and 2012. Their performance was compared to that of students completing a traditional group paper assignment in 2010 and 2011. Both student groups had the same instructor (Altamirano and Jaurez, 2012). Self-reported student data also suggest that the use of the GDM can be beneficial for learning, collaboration, engagement and motivation as well as for creativity and critical thinking. Students on two courses, Sustainability and Computer Ethics, were asked to rate various features and impacts of the GDM on a scale of 1 to 5 (with 5 being the most favourable). The 25 Sustainability course students saw the GDM as valuable in increasing "depth of learning" (4.34), "'inter' and 'intra' team positive competition" (4.32), "engagement" (4.20) and "motivation" (4.16). The 18 students in the Computer Ethics course considered that the GDM increased "creativity and imagination" (4.44), "critical thinking skills" (4.33), "team collaboration and communication" (4.17), "engagement" (4.17), "motivation" (4.06) and "depth of learning" (4.00).

Source: 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, *http://dx.doi.org/10.1787/5k480sj9k442-en.*

Educators and policy makers should consider online laboratories as a promising way of increasing access to a wide range of experimental learning. Using online laboratories only requires access to the Internet and allows teachers and students to access more experimental equipment than a single school can generally provide. While remote laboratories can give students access to expensive equipment, virtual laboratories can allow them to vary the conditions for the experiments. Online laboratories are thus a good complement to – or substitute for – school science labs. The use of online laboratories can be at least as effective in terms of learning as the use of on-site physical equipment, and many resources are freely available on the web.

As promising innovations particularly for science instruction, online laboratories can be expected to offer the following potential benefits:

- **Lower-cost access**. Online laboratories may help bridge the digital divide by providing students with faster access to experimental learning at a relatively low cost (Burd, Seazzu and Conway, 2009; Flint and Stewart, 2010; Nedungadi and Raman, 2011; Jara et al., 2011;

Ku, Ahfock, and Yusaf, 2011). Simulations may be less expensive than experimental hardware, although "little empirical data exists on the actual costs of providing online laboratory access at scale" (Jona et al., 2011).

- **Flexible access**. Online laboratories can enable flexible access to practical experiments, allowing increased study time that is not tied to a specific timetable or location. (Ku, Ahfock, and Yusaf, 2011; Almarshoud, 2011).
- **Better learning**. Online laboratories can help support student understanding and achievement at least as well as physical hands-on learning does (Yang and Heh, 2007; Pyatt and Sims, 2012; Chini et al., 2012). Virtual manipulatives may be used in a blended format together with physical manipulatives of experimentation to further increase student understanding (Nedungadi and Raman, 2011; Olympiou and Zacharia, 2012).

An excellent example is the online laboratories for upper secondary physics and mathematics developed by Amrita University in India (Box 4.6).

Box 4.5. **Eco-Virtual Environment (EVE) of City Academy Norwich, the United Kingdom**

The Eco-Virtual Environment (EVE) project of the City Academy Norwich in the United Kingdom, is a virtual world simulation focusing on environmental challenges. Students participate in the virtual world as part of a team and as creators of learning materials. In the EVE project "students are presented with an island that has growing energy demands". They are then required to "specialize and collaborate in order to design an energy network", while their "decisions will have real-time feedback in terms of power, finance and environment". The real-time feedback will then guide students' further decisions. With the teacher "in the driving seat", the simulation is meant to be organic and flexible. In terms of technology, the EVE project "looks and feels like a high-end computer game", using Google docs for the data feed and Opensim, making "the simulation usable on most computers without severe compromise to graphical quality".

Initial testing of the EVE project has suggested some positive impact on student communication and problem solving, although the impact on student learning is still to be further investigated. Limiting student communication only to the virtual world seems to generate better problem-solving results than the combination of virtual world and real-life discussions, especially for students who struggle in a traditional classroom context. One part of the 30-student test group "were given a dynamic environmental problem to solve [in small groups] by sitting around a table and discussing their actions". The other part, also in small groups, "were given the same problem but limited to 'in world' communication only"; they eventually "generated better solutions and produced more profit with less environmental damage". In the follow-up interviews, the students in the "in world" groups felt they owed these results to highly focused and measured communication. The students in the other groups reported "that their discussions often varied to non-learning based topics and arguments between team members were frequent". In terms of understanding, the quality of answers to questions such as "'If renewable sources of energy are so good why do we still have coal power stations?" were considered to be superior after time spent in the EVE.

Source: 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, *http://dx.doi.org/10.1787/5k480sj9k442-en*.

Collaboration through technology

Collaboration through technology can enhance students' interaction, engagement, learning and thinking skills, in addition to increasing the flexibility and diversity of their educational experience. Technology-supported collaboration can enhance students' awareness of global challenges and develop their understanding of other cultures.

Box 4.6. **OLabs Online laboratories and the Collaborative Assessment Platform for Practical Skills (CAPPS) of Amrita University, India**

To help teachers to deploy online laboratories (OLabs), Amrita University has developed a multilingual Collaborative Assessment Platform for Practical Skills (CAPPS). OLabs include simulations based on mathematical models, interactive animations, remote equipment access and other rich-media learning material to enable students and teachers to conduct experiments in an interactive and collaborative manner. They can be used also as "a pre-lab learning tool to provide additional activities, to support teaching or learning of a concept and to evaluate the student". The cloud-based CAPPS is meant to allow a formal assessment not only of student understanding, but also practical skills related to science. These skills include both procedural skills (related to conducting experiments) and reporting skills (such as writing a lab report). For example, in an online environment, students' procedural skills could be assessed by asking them to select the right apparatus for an experiment or outline the sequence of steps. Assessment is based on a multiple choice format with immediate feedback and all the student's activities in an online environment can be tracked. These features can "help students focus and redirect their efforts to the appropriate task needed for mastery of a skill" (Nedungadi and Raman, 2011).

In addition to improving access, the OLabs and CAPPS appear to improve student performance in understanding science. The use of OLabs with physics students has shown significant pre/post-test gains ($t(26) = 6.58$, $p < .001$, $M = 3.33$ $SE = 0.51$). The collaborative research study shows OLabs appears effective based on the examination of the average group scores between mean pre and post tests (mean group performance gain in a paired t-test was $t(9) = 1.83$, single-tailed $p = 0.0001$). Total touch interaction with the tabletop and the average total time spent by a group were found to be the two main collaboration factors contributing to the performance gain – implying students working "jointly on the project, discussing together and taking turns interacting with the tabletop". Most students were positive, with 76% agreeing that OLabs improved their subject understanding and 70% that CAPPS provided them with greater control over their learning experience during the pilot testing in nine schools in Kerala in India. Of the 49 teacher workshop respondents, most agreed that OLabs would improve a student's understanding of a subject (87%) and enable students to learn faster (89%).

Source: 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, *http://dx.doi.org/10.1787/5k480sj9k442-en.*

Educators and policy makers should consider technology as a way to increase collaborative learning – including over long distances and between different cultures. Policy makers could facilitate this process by creating platforms for international collaboration among schools, classes, teachers and students. Collaboration can be supported by tools such as cloud computing, video-conferencing, or online platforms. New technologies allowing for real-time communication make international collaboration much easier than in the past.

For example, as a Catalyst project, students and teachers at Scofield Magnet Middle School in the United States and Shandong University Middle School in the People's Republic of China collaborated on a water quality project with support from scientists and other experts. While the students in the United States examined the quality of their local groundwater, the Chinese students explored the Huangshui River Basin – one of the most polluted river systems in China. Students measured water quality, topography, drainage, flora and fauna, as well as the impact of urban development on water quality. With the help of technology, the project enabled students in both countries to compare their findings and reflect on the challenge of water quality internationally – and to increase their awareness of another culture.

In technology-enabled collaboration, students work together (in groups) and/or interact with each other to enhance their learning with the help of various technologies (Resta and Laferriere, 2007; Zhu, 2012) – often with facilitation from the teacher (Resta and Laferriere, 2007). When combined with other learning approaches, technology-enabled collaboration can form a part of project- or problem-based learning or supplement face-to-face learning (Resta and Laferriere, 2007). Technology-enabled collaboration models may include in-built assessment features taking into account also team performance and/or collaborative activity (Zhu, 2012).

As a promising model for STEM education and other disciplines at various education levels, collaboration through technology may improve:

- **Flexibility**. Technology enables students to collaborate and practise at "their own pace", beyond the formal classroom hours and without limitations of physical location (Resta and Laferriere, 2007; Zhu, 2012).
- **Cultural diversity**. Technology can significantly increase the chances for intercultural interactions by broadening the scope of collaborations to distant locations, even across borders (Resta and Laferriere, 2007; Crawley et al., 2008; Karpova, Correia, and Baran, 2009; Rogers, 2011; Rautenbach and Black-Hughes, 2012).
- **Student learning**. Technology-enabled collaboration may support student learning, in both individual and group outcomes (Resta and Laferriere, 2007; Thompson and Ku, 2010; Kelly, Baxter and Anderson, 2010), although not necessarily more than face-to-face interaction (Tutty and Klein, 2008). There can also be cross-cultural differences (Zhu, 2012). In general, positive results from co-operative learning on student achievement have been shown to depend on group learning goals and individual accountability (Slavin, 2010).
- **Student interaction and engagement**. Technology-enabled collaboration can encourage students' group work skills, interaction and engagement (Nevgi, Virtanen and Niemi, 2006; Resta and Laferriere, 2007; Nussbaum et al., 2009; Kelly, Baxter, and Anderson, 2010). However, students do not automatically adopt "active learning strategies" (Wang, 2010) and activity may differ across cultures (Zhu, Valcke and Schellens, 2009; Zhu, 2012). In general, co-operative learning has shown clearly beneficial results on affective student outcomes (Slavin, 2010).
- **Students' thinking skills**. Online collaboration may enhance higher order thinking even more than face-to-face collaboration through "more complex, and more cognitively challenging discussions" (Resta and Laferriere, 2007). This can also be the case for "questioning behaviours" and "project performance" (Tutty and Klein, 2008).

Two good examples of collaborative online learning are Renmin University's project which combined in-class lectures and self-study with exploratory, project-based and collaborative online learning facilitated by an online platform (Box 4.7), and the National Research Irkutsk State Technical University's use of technology for collaborative problem generation and solving (Box 4.8).

Box 4.7. **Collaborative online learning platform of Renmin University, China**

Renmin University in China created blended courses which used its collaborative online learning platform to combine in-class lectures and self-study with exploratory, project-based and collaborative learning. It developed three blended courses: 1) Multimedia Technology and Application; 2) Introduction to Program Design; and 3) Database Technology and Application. Students were able to solve problems, simulate using software and hold group discussions on the platform. The in-depth online collaborative exploration was preceded by lectures covering "basic points of the curriculum". Crucially, teachers also provide timely long-distance mentoring for students, "arrange online discussions based on the actual progress" and "help students solve problems along the conceptual framework". Drawing from the feedback and analysis, the supporting Zask platform was gradually improved from the initial version to a web-technology supported YOU-niversity platform version 2.0. The improved platform combines "learning, sharing, collaboration, data collection and evaluation functions" and can be visited "through remotely accessible virtual environments".

Initial indications suggest a positive relationship between online collaboration and student performance. In terms of collaboration, most "students have activated their accounts in the platform" and "taken part into online discussion and activities" (98%). Active collaboration in the platform seems to correlate with good performance in the Introduction to Database System course – for example seven of the top ten students in academic achievement were also in the top ten for collaborative activity. In addition, most students responding to a survey on its effectiveness perceived online collaborative learning to be supportive to their learning.

Source: 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, *http://dx.doi.org/10.1787/5k480sj9k442-en*.

Box 4.8. **The MoPS collaborative problem-solving model of National Research Irkutsk State Technical University, Russia**

The MoPS model being developed by National Research Irkutsk State Technical University in Russia focuses on interactive, collaborative problem solving and peer assessment. It covers both problem generation and problem solving – the problems are meant to be customised for the "preferred cognitive styles, temperament, physiological [traits] and age" of the participants. The model includes a peer-assessment component – expected also to act as a motivator for students – based on an automatically calculated rating of the problem generation and solving process. While "the initial rating for new participant is 0", correct answers increase the ratings both of the student who disseminated the problem and the student solving the problem. In turn, "incorrect answers decrease the ratings". If either all or none of the answers are correct, the problem will be disregarded as too simple or too difficult – a "problem is considered being valid if a defined percentage of correct answers had been reached in the predefined interval of time". The role of the teacher is to "direct and coordinate cognitive activity of learners through active participation, such as generation of controversial tasks [or] setting of time limit for solving tasks". In terms of technology, MoPS works flexibly on mobile devices such as a personal computer or a smartphone. Problems can be generated and solved through diverse media such as photos, videos or audio files, while "the social network pattern provides a good distribution mechanism for a user-generated content" and stimulation of student activity. The model is based on Windows and Android operation systems and on peer-to-peer technology. It can be used with or without an Internet connection.

Source: 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, *http://dx.doi.org/10.1787/5k480sj9k442-en*.

Real-time formative assessment

Technology significantly facilitates the use of formative assessment – that is, frequent, interactive assessment of student progress and understanding (OECD, 2005a). Clickers, tablet computers and other kinds of technology enable instantaneous interaction and feedback between teachers and students. In real-time formative assessment, software enables a variety of inputs to be used for student assessment including open format replies, student questions, pictures or mathematical formulas (Enriquez, 2010; Briggs and Keyek-Franssen, 2010; Kohl et al., 2011; Gardner, Kowalski and Kowalski, 2012; Universidad de las Américas Puebla, forthcoming). Some of the software is freely available. Real-time formative assessment can be combined with various instructional models. Box 4.9 gives an example of the use of technology to support real-time formative assessment in the United States.

Box 4.9. **Real-time formative assessment in the InkSurvey of Colorado School of Mines, (United States)**

In the United States, the Colorado School of Mines has explored the effective use of "mobile technology to facilitate real-time formative assessment" and support student creativity. The real-time interaction aims to engage "students in their learning", while "the instantaneous feedback to the instructor informs subsequent instruction". Towards this end, Colorado School of Mines is improving and validating its InkSurvey software – "a free, web-based tool that allows students [with the help of tablet computers] to use digital ink to respond to open-format questions posed by the instructor". As part of the exploration effort, a creativity course in physics facilitated by InkSurvey has been "developed and delivered to a variety of student populations" – an effort leading also to an "entirely new direction of investigation" of developing a tool for creativity assessment in physics. The project has been scaled up to give high school and community college teachers access to InkSurvey in their classrooms. It has been used in undergraduate and graduate-level classes at the Colorado School of Mines and Universidad de las Américas Puebla, Mexico.

Coupling real-time formative assessment using InkSurvey with interactive computer simulations seems to increase students' conceptual understanding. Initial trials on the creativity course in physics suggest a positive impact on student creativity (See Box 1.5 in Chapter 1). For example, while free play with interactive simulations increased student scores in chemical engineering by "~12%, or a full grade level", guided play with the help of InkSurvey-based real-time formative assessment increased scores "an additional ~21%, or two more full grade levels" (Gardner, Kowalski and Kowalski, 2012).

Source: 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, *http://dx.doi.org/10.1787/5k480sj9k442-en*.

Educators and policy makers should consider using real-time formative assessment to enable more personalised learning. The immediate feedback it provides allows teachers to personalise their instruction to the needs of individual students or to specific groups of students. Real-time formative assessment can also help ensure every student participates in classroom discussions – something that does not generally happen in group instructions, for example because of time constraints or shyness.

As a promising educational innovation, real-time formative assessment could enhance:

- **Targeted instruction**. Real-time formative assessment allows teachers to monitor student learning as it happens and better adjust their teaching to the needs of individual students (Enriquez, 2010; Briggs and Keyek-Franssen, 2010; Kohl et al., 2011; Gardner, Kowalski and Kowalski, 2012).

- **Student learning**. Real-time formative assessment can increase student achievement by promoting students' reflection about the needs of and engagement in their own learning (Enriquez, 2010; Briggs and Keyek-Franssen, 2010; Gardner, Kowalski and Kowalski, 2012; Wu et al., 2012).
- **Problem solving and creativity**. Real-time formative assessment provides avenues for assessing different types of activities and variety of student skills such as problem solving or creativity – potentially enhancing the acquisition of these skills (Looney, 2009, 2011a; Enriquez, 2010; Kohl et al., 2011; Wu et al., 2012; Gok, 2012).

Aligning a skills-based curriculum with technology

Using technology to align with skills-based curricula can promote more accurate assessment of the variety of skills included in STEM+ curricula and standards. While it is becoming increasingly common to develop these kinds of skills-based curricula, their eventual impact on actual teaching and learning also depend on the availability of adequately aligned support systems (Ananiadou and Claro, 2009; Looney, 2011b; Kärkkäinen, 2012). This is particularly true for student assessments, but also for learning materials, teaching guides and teacher professional development (Ananiadou and Claro, 2009; Kärkkäinen, 2012). Adequate measurement is needed to truly promote certain skills, to give teachers an incentive to teach students in that way (Looney, 2009). In contrast, assessments that are poorly aligned with standards and curriculum make it "impossible to draw valid conclusions about the success of student learning" (Looney, 2011b). Although "no system can achieve perfect alignment" (Looney, 2011b), technology can become a great support in developing adequate measures for approaching this goal.

As a promising innovation for advancing STEM+ skills, technology can improve adequate curriculum alignment through:

- **Adequate assessment**. Technology can help measure complex skills such as reasoning or problem solving through measures such as essays, blogs or virtual learning environments (Looney, 2009, 2011b; Ramirez-Corona et al., 2013).

In Mexico, Universidad de las Américas Puebla has designed support systems for developing the 21st century skills needed by engineering students (Box 4.10). The work took place in the framework of a recent reform of the undergraduate curricula around nine department-wide "pillar" courses.

Conclusion: the potential of technology to change classroom practices

Technology holds significant potential for expanding the range of learning opportunities available to students and for the formative assessment of a wide range of skills for innovation. The variety of learning opportunities and personalisation technology can offer may make education more interesting and enjoyable for students.

Catalyst projects offer examples of technology-supported education that provide wider ranges of experimentation and learning-by-doing than are possible without technological support. Simulations provide one route to greater experimentation. Online laboratories (remote or virtual) using simulations can enable relatively low-cost flexible access to experiential learning. They can allow increased study time, and offer access that is not restricted to a specific timetable or location.

In addition, technology-supported simulations can allow the study of subject matter that would be almost impossible otherwise. Parents are likely to be unhappy if their children were to work with radioactive strontium-90 in a live laboratory. Remote or virtual laboratories offer the experience of studying and working with radioactivity safely. Nor can any school afford an unlimited supply of physical experimental resources. Online and remote laboratories, as well as other virtual environments, can be used to complement the resources available on site and enhance teachers' and students' teaching and learning opportunities.

Box 4.10. **Support systems for 21st century skills in Universidad de las Américas Puebla, Mexico**

The Universidad de las Américas Puebla has developed support systems for developing the 21st century skills needed by engineering students. These tools include standards, professional development opportunities, learning environments, instruction activities and assessments. The systems particularly target nine "pillar" courses for undergraduate chemical, food and environmental engineering students. They focus on increasing active student participation as well as peer- and team-interactions, and improve feedback processes and formative assessments. For example "several problem-solving learning environments (PSLEs) for the junior course entitled Kinetics and Homogeneous Reactor Design" were developed. The course focused on meta-cognition in order to develop engineers' ability to solve workplace problems that may differ from those encountered in classrooms. Towards this end, "the instructor created a supportive social environment in the course and inserted a series of question prompts during PSLEs, as a form of coaching where the problem to be solved was represented as a case". The cases served as "instructional supports" and included "worked examples, case studies, structural analogues, prior experiences, alternative perspectives, and simulations". Pre- and post-assessments suggests "a significant ($p<0.05$) increase in student metacognitive awareness" as measured by a 52-item Metacognitive Awareness Inventory (MAI). The result was "also noticed by means of the embedded MAI prompts while solving different kinds of problems [...] throughout the course" (Ramirez-Corona et al., 2013; see also Ramirez Apud et al., 2012).

Tablet computers and associated technologies were used for assessments to "improve chemical engineering teaching and learning by creating high-quality learning environments that promote an interactive classroom while integrating formative assessments into classroom practices". With tablet computers for every student, the associated technologies OneNote, InkSurvey, and Classroom Presenter were used in two junior and two senior chemical-food engineering courses. The objective was to "gauge student learning in real time, provide immediate feedback, and make real-time pedagogical adjustments as needed, especially in the redesigned problem-solving learning environments". Semi-structured interviews with three students suggest that the use of tablet computer technologies "increased their motivation to participate in class and enhanced their scores in graded work-products". Also activity in classrooms and learning experiences seemed to improve and trigger student reflection together with real-time feedback (Palou et al., 2012). Similar results were also obtained with structured interviews of 12 graduate students in advanced food chemistry (Gutierrez-Cuba, López-Malo and Palou, 2012).

Source: 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, *http://dx.doi.org/10.1787/5k480sj9k442-en*.

Technology also increases the possibilities for intercultural collaboration, overcoming geographical distance and formal classroom hours, such as the way middle school students in Connecticut in the United States and Shandong Province in China were able to work together despite being a world apart, conducting real scientific research into water pollution. Similarly, undergraduates at Coventry University in the United Kingdom collaborated and planned teamwork in a virtual built environment project that required them to go through all the stages of a construction project with peers in Canada. These projects provided students with an opportunity to experience international collaboration, to gain insight into other cultures and differences, and to be exposed to multicultural communication. This type of collaboration closely emulates the collaborative nature of today's international STEM professions.

Finally, technology facilitates real-time formative assessment and some forms of skills-based assessments that improve monitoring of student learning, and supports personalisation of teaching. Real-time formative assessment allows teachers to monitor student learning as it happens, and to immediately adjust their teaching to the needs of individual students. It may also enable the active participation of more students in the classroom discussion. Technology-supported assessment enables students' skills development to be monitored, and the skills they still need identified in a more comprehensive way than would be possible without technology.

Technology-enhanced educational models offer not so much a technological or a cost challenge as a pedagogic one. The study shows that Catalyst projects typically require simple equipment (computers, tablets, mobile phones) with Internet connections. Although the cost of these depends on the country or regional context (particularly relative to average or typical income levels), these are relatively low-cost resources which are often already familiar and available to teachers, especially in OECD countries. Many digital resources are also freely available to teachers: these include simulations in virtual environments (remote or online laboratories, games) and software for real-time formative assessment.

To adopt these new models, however, teachers need to revisit their pedagogy and this may incur the greatest cost and challenge. The efficacy of technology-supported models does not come from technology alone, but from the pedagogy that it supports. Without good pedagogic resources and a good understanding of how to use technology to foster deeper learning, these models may not yield the expected outcomes. Real-time formative assessment allows teachers to see in real time what students think and know, but they still have to use this information in their teaching to encourage students to reflect more deeply and to challenge their misconceptions. Experiential learning is most likely to provide expected improvements in conceptual understanding and scientific inquiry skills if teachers encourage students to repeat their experiments and provide students with robust scaffolding to understand them.

Online resources for schools and self-directed learning

Of course, there are numerous other ways through which ICT, the Internet and digital technologies can support and improve education and learning. One of the most visible ways is through the spread of e-learning, the availability and use of educational resources (open educational resources) and through new forms of courses (massive open online courses or MOOCs) available for teachers, schools and individuals engaging in self-directed learning. In this section we provide a brief discussion of the potential of these developments.

E-learning

The origins of e-learning can be traced back to the first form of education that went beyond the boundaries of the classroom: distance education. While distance education was already remarkably common in the late 19th century, it emerged as a more solid educational option in the second half of the 20th century, thanks mainly to the development of new technologies and the growing demand for higher education. The creation of the Open University in the United Kingdom in 1969 and of the University of Distance Education (UNED) in Spain in 1972 represent two milestones in this form of education, which gained prominence in subsequent years mainly as an option for students located in distant geographical areas who lacked access to educational institutions.

Distance education evolved along with innovations, and so its format has constantly adapted to the new opportunities represented by emerging technologies. The first forms of distance education essentially relied on printed and mailed material, with no use of ICTs. The first generation to adopt technological tools for distance education used the telephone and television. The second generation incorporated other media, such as facsimile transmission, audiocassettes and videocassettes. The third generation principally used computers, opening up the possibilities for education delivery. Finally, the emergence of the Internet and high-bandwidth computer technologies started a fourth generation of distance education, bringing about new possibilities and a faster pace of change (Keairns, 2003).

In general, e-learning refers to the use of information and communications technology (ICT) to enhance and/or support learning in education. By this definition, e-learning encompasses a wide range of modalities, everything from courses offered on campus but with online access to coursework and e-mail communication, to programmes offered entirely online.

E-learning courses have two unifying features: they are offered by a physical, often campus-based institution, and they are tied to the Internet or another online network. From the least to the most intensive form, e-learning courses can be divided into the following delivery modes (OECD, 2005b):

- **Web-supplemented courses** are now the baseline in OECD countries for ICT presence in tertiary education. They refer to the use of the web for passive elements of the course and generally encompass some level of e-mail communication as well as an online platform for posting course information, materials, assignments and resources or external links. In this mode of e-learning there is no reduction of face-to-face time.
- **Web-dependent courses** are those for which an online element is introduced for key "active" elements of the course, including online discussions, assessments and project-based or collaborative work. Here, as with web-supplemented courses, there is still no significant reduction in face-to-face time, but these online elements are mandatory for all students.
- **Mixed mode courses** begin to replace or supplement face-to-face time with online elements, although classroom hours continue to be a significant part of any course. Students in these courses are required to participate in online activities as a vital part of their coursework. The mixed mode course model might comprise of online, asynchronous course lectures followed up by in-class discussions or learning seminars. Alternatively, lectures could be carried out in the traditional face-to-face manner but be complemented by online mini-seminars or tutorials. Mixed mode e-learning often exists at the programme level and, in such cases, refers to a programme of study that is comprised of both traditional and online courses.
- **Fully online courses** can be taken by students living anywhere in the world provided that they have an interface (e.g. computer, phone, handheld device), the necessary software applications and access to the Internet. With the exception of orientation, exams and support services, this type of course (or even programme) is delivered entirely on line and/or through "learning objects" with little to no face-to-face time.

An important distinction between the different forms of e-learning relates to their time and place dimensions. E-learning can involve synchronous or asynchronous instruction: it may take place at a set time with an instructor or peers, or it may be taken independently at any time. E-learning can occur when students and instructors are in the same room or in different places altogether. For instance, students may study online but in a computer lab on campus, supervised and assisted by a handful of instructors. Even fully online education does not necessarily happen at a distance: students may take all of their courses on line but still on campus. Depending on the specificities of the course design, e-learning may relax place and time constraints to a greater or lesser extent, ranging from studying "anytime, anywhere" to "at a specified time and specific place".

Moreover, it may be possible to adapt the pace of learning to the learner, not only in terms of total time to complete a course or programme, but also the route each learner takes to arrive at the end of the course. When courses are designed around learning objects, for example, students may choose to skip lessons on topics they have already mastered or to view lessons in a different order. In this respect, the learner enjoys more freedom than would generally be the case in a conventional environment.

E-learning is becoming increasingly relevant in education, mainly in the field of higher education. Its expansion is due not only to the emergence of new ICTs or the development of new pedagogical approaches, but just as importantly to the need to broaden access to higher education in response to the increased demand and find additional financial resources at a time of concern for the higher education system's sustainability. In that sense, e-learning is viewed not only as a format for delivering education, but also as a means of acquainting students with the use of ICT in a context where digital literacy is increasingly important. It is also seen as an opportunity for a more efficient organisation and management of higher education institutions (HEIs).

E-learning has grown steadily in recent years as an option for higher education and is expected to expand progressively around the world. Although data and statistics on e-learning are difficult to find, which makes it complex to accurately evaluate the extent to which HEIs have adopted it, almost all the existing evidence indicates a steady growth (Helmeid and Vincent-Lancrin, 2014). Different indicators support this perception. First, the global market for "self-paced e-learning" generated revenues of USD 42.7 billion in 2013 and is expected to reach USD 53 billion by 2018 (Ambient Insight Research, 2014). Second, some of the countries where e-learning is more prominent show a significant expansion in course offerings. In the UK, around 35% of HEIs offered at least one e-learning course in 2010 (White et al., 2010). In Australia, a study by the Flexible Learning Advisory Group (FLAG, 2013) exclusively focusing on vocational education and training (VET) showed that 48% of all related activity involved some form of e-learning in 2013. In Korea, e-learning courses comprised 16.9% of all university courses – of which 38.9% were fully online, 14.2% blended and 46.9% web-supplemented or web-dependent – in 2009 (Hwang et al., 2010). In the United States, evidence presented by the National Center for Education Statistics shows that 66% of HEIs offered distance education in some of its forms in 2006-07, of which 77% was fully online and 12% blended (Prasad and Lewis, 2008). Finally, demand for e-learning can be understood by studying enrolment. Figures on student participation in the United States show that in the autumn of 2012 7.1 million students were enrolled in at least one online course (meaning they could also be enrolled in face-to-face learning), compared with 1.6 million in 2002 and around 4.0 million in 2007. This represented around a third (33.5%) of all students who were enrolled in higher education in 2012, compared with 9.6% in 2002 and 21.6% in 2007, with online enrolment showing a faster growth rate than total enrolment (Allen and Seaman, 2014). While the rate of growth of online enrolment may have slowed down, it is still growing (around 3.5% growth in 2013) and above total enrolment (around 1.2%) (Allen and Seaman, 2015).

Open educational resources

The use of digital technologies in education has diversified away from an undifferentiated concept of e-learning. One very important development has been and still is the rise of open educational resources (OERs). OERs are defined as teaching, learning and research materials that make use of appropriate tools, such as open licensing, to permit their free reuse, continuous improvement and repurposing by others for educational purposes.

This definition is based on the common definitions of OER used by OECD/CERI in previous publications (OECD, 2007), the William and Flora Hewlett Foundation, and the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Box 4.11).

Box 4.11. **Defining open educational resources**

OECD-CERI definition

"Open educational resources are digital learning resources offered on line (although sometimes in print) freely and openly to teachers, educators, students, and independent learners in order to be used, shared, combined, adapted, and expanded in teaching, learning and research. They include learning content, software tools to develop, use and distribute, and implementation resources such as open licenses. The learning content is educational material of a wide variety, from full courses to smaller units such as diagrams or test questions. It may include text, images, audio, video, simulations, games, portals and the like."

William and Flora Hewlett Foundation definition

"OER are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and repurposing by others. Open educational resources include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials or techniques used to support access to knowledge."

Whilst these definitions differ slightly, they both highlight the necessary condition of educational materials being free to access and open for (re-)use and repurposing (combining, adapting, expanding and putting to a new purpose) in order for them to be considered OERs. The William and Flora Hewlett Foundation definition explicitly mentions the requirement for the resources to have been licensed to permit free and adaptive use, whereas the CERI/OECD definition focuses on the condition that such free and adaptive use should be possible (which may also be a technical issue). In both cases, the list of examples of educational resources shows variety without limiting what type of educational resources OERs can be, although with the CERI/OECD definition there is an expectation that OERs will be digital learning resources (even if they may be accessed off line later).

Sources: Hylén, J. et al. (2012), "Open educational resources: Analysis of responses to the OECD country questionnaire", *http://dx.doi.org/10.1787/5k990rjhvtlv-en*; William and Flora Hewlett Foundation website, "Open educational resources", *www.hewlett.org/programs/education/open-educational-resources*.

At the heart of OERs is the possibility of taking original work from other providers and being able to adapt and repurpose it to produce a new learning resource. In this sense, "open" means both free to access and free to change. It is for this reason that one of the central characteristics of an OER is liberal licensing, for example through Creative Commons, which facilitates this process.

The OER movement grew as an approach to education which tried to remove barriers to teaching and learning, using new digital technologies to share educational resources openly across the global community of educators and learners. The steps taken by the Massachusetts Institute of Technology (MIT) gave strong impetus to this trend. MIT created OpenCourseWare (OCW) in 2001, and then formed the OCW Consortium in 2005. By 2007, it had published all of its courses on line. The movement toward open sharing of educational resources has grown intensely over recent years, with many additional education institutions following suit.

OER is not just about "putting stuff on the web", but can be seen as leading to social innovation. Social innovations usually occur in the non-market sector, meaning they are not governed by the profit motive. According to Murray et al. they can be defined as: "new ideas (products, services and models) that simultaneously meet social needs and create new social relationships or collaborations. In other words, they are innovations that are both good for society and enhance society's capacity to act" (Murray, Caulier-Grice and Mulgan, 2010). Their impact is not simply measured by whether OERs are being produced or even being used, but whether they are having a transformative effect on the way teachers and learners collaborate (Box 4.12).

Box 4.12. **Open educational resources as a catalyst for innovation**

A recent OECD/CERI study has focuses on the contribution of OERs to six key educational challenges that education systems face today (Orr, Rimini and Van Damme, 2015). These concern teaching and learning, cost containment, the distribution of high-quality educational resources, and reducing the barriers to learning opportunities, which together can improve the quality and accessibility of teaching and learning provision. They are:

Fostering the use of new forms of learning for the 21st century

New forms of learning are required to provide learners with a learning experience that better facilitates personal development and success in a knowledge society. These include the use of approaches to learning which involve learners as a community in the development of their own learning materials and the support of other learners. The ability to easily adapt and share OERs supports this objective.

Fostering teachers' professional development and engagement

Teacher development and engagement has been shown to be key to effective learning. The adaptability of OERs allows teachers to revise and tailor their educational resources to provide a better fit to the educational environment in which they are teaching. Such an opportunity is also expected to lead to a higher level of collaboration between teachers.

Containing public and private costs of education

Increasing participation in education systems across the world leads to a challenge of sharing the cost of high-quality learning materials between public budgets and private households. OERs could reducing these costs by allowing resources to be developed, shared and updated more cost effectively.

Continually improving the quality of educational resources

The dynamics of a knowledge society lead to three challenges for educational resources: they must reflect new developments in the subject area they cover, they must reflect new learning theories in order to better support high-quality learning, and they must be fit for purpose for the expected learning outcomes and the diverse groups of learners who are using them. The adaptability of OERs makes it possible for educational resources to keep pace with these dynamics.

Widening the distribution of high-quality educational resources

High-quality resources for education are being produced and used in some educational institutions, for some groups of learners and in some countries. The ability to share OERs could help break down barriers to high-quality education by ensuring a more even distribution of high-quality resources. This can build bridges between countries, between informal learning and formal education, and facilitate lifelong learning.

Reducing barriers to learning opportunities

Many learners are excluded from high-quality learning opportunities because of the requirements of place, time and pace of learning. OERs offered as digital resources enable educational resources to be accessed beyond a set place and time of provision, and allow them to be provided at an appropriate pace for the learners.

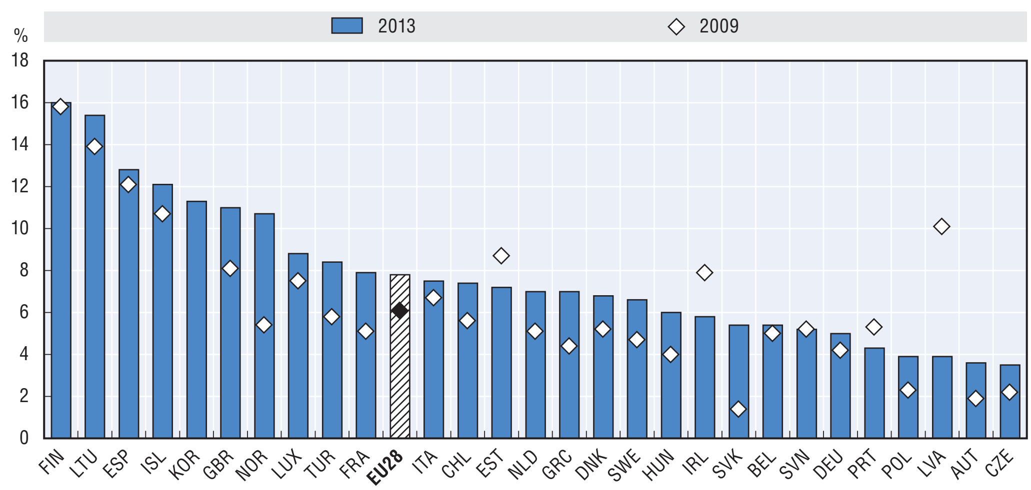
Source: Orr, D., M. Rimini and D. Van Damme (2015), *Open Educational Resources: A Catalyst for Innovation*, *http://dx.doi.org/10.1787/9789264247543-en.*

Online courses

In addition to transforming classroom practices, digital technologies open up opportunities for self-directed learning and continuous professional development. In particular, massive open online courses (MOOCs) appear to be well-suited to enabling people to update their competencies over their lifetimes by overcoming time and resource constraints. Online resources can thus offer a partial solution to the challenges of developing, activating and effectively using skills.

In the last five years, online education has found its peak moment with the emergence of MOOCs. MOOCs are fully fledged courses of lectures available on line to serve a wide variety of purposes. With MOOCs, the term "massive" clearly implies a significant scale. Coursera, one of the leading educational platforms, has now reached approximately 17 million people while enrolments in EdX peaked at 5.3 million in June 2014. In 2013, 7.8% of Internet users in the European Union had followed an online course against 6.9% in 2009. Across the 26 OECD countries for which data are available, 7.6% of people followed an online course, ranging from 16% in Finland down to and the lowest levels in Austria, Czech Republic and Poland (Figure 4.1).

Figure 4.1. **Individuals participating in an online course**



Source: This chart has already been published in OECD (2016), "Skills for a Digital World. 2016 Ministerial Meeting on the Digital Economy Background Report", *http://dx.doi.org/10.1787/5jlwz83z3wnw-en.*

StatLink http://dx.doi.org/10.1787/888933274772

The latest demographic trends collected from EdX paint a picture of an average learner who is highly educated (69% have a bachelor's degree) predominantly male (78%) and, in 29% of cases, American (Ho et al., 2015). On average, 17% of participants explore more than half of the course content and 8% earn a certification (Ho et al., 2015). The majority of learners took part in computer science courses (36%) followed by STEM subjects (26%) and humanities (21%). Across disciplines, it is interesting to notice that the computer science and STEM courses were mostly serving a younger, male, international and less educated population, whereas humanities courses had more gender balanced, older and educated participants.

However, these numbers do not show how much MOOCs contribute to student learning or skills development. On average, only 5% of no-fee participants in EdX in complete these courses (Ho et al., 2015). These high dropout rates can be explained by several factors:

learners' motivation to start a course, incentives driving completion as well as the inherent difficulties that completing a MOOC may entail. As an illustration, educational research has shown that the ability to self regulate, which is particularly important for online courses, does not simply emerge from studying on line but is a precondition for effective self-directed learning (Orr, Rimini and Van Damme, 2015).

Learners taking part in MOOCs provided by academic platforms such as Coursera and EdX are driven by diverse motivations and incentives. Some may enrol a course out of personal curiosity about a specific subject, some may want to deepen their knowledge or strengthen their skills in a specific domain, and others may enrol to prove their interest and knowledge to the eye of a current or potential employer (Zhenghao et al., 2015).

The main motivations for Coursera's learners to complete their course appear to be to improve their current job or finding a new one (52%) and to achieve an academic objective (28%). Looking at outcomes, 26% of those with professional ambitions found a new job while only 3% obtained a salary increase or a promotion after the successful completion of the MOOC. Among the educational benefits, only 12% of academic objective seekers actually completed the prerequisites for academic programmes while 64% gained essential knowledge for their study field (Zhengao et al., 2015).

The growing popularity of the MOOC model has engendered various other initiatives in the field of education (Box 4.13), in-company workforce training or skills training for the unemployed. International organisations are now also partnering with MOOC platforms to develop specific courseware.

Box 4.13. **The MOOC programme in the Israeli education system**

An ever-growing number of leading universities (including MIT, Stanford, Princeton, Yale, Harvard and Duke) upload courses to the Internet in a variety of fields. These online courses are supervised by senior lecturers at the universities and by the actual creators of knowledge and are offered to the public at large, free of charge. The courses are taught at a very high level and enable anyone to study at their own pace. There is no limit to the number of participants and they are available anywhere, anytime.

Such MOOC courses could offer a revolution in the world of education. Tens of thousands of people register for courses which are open to everyone. However, studies indicate that only few complete them – only around 4-20% of those who register for the courses. One reason for this is that it is very difficult to sit and learn alone in an online academic course, with no connection or human contact. The Ministry of Education, understanding that there is no replacement for human contact even in the technological age in which we live, joined forces with the Education Cities Network to supplement the online knowledge and content being made available internationally with three aspects:

1. the team model – learning as part of a group
2. principles of the reversed classroom
3. use of free social media.

The team model means groups learn together, like a sports team. Each person has a significant role and each of the team members is committed to the group and the joint goal – completing the MOOC course successfully. In addition, each student in the group is also a teacher: not just learning the course material but also committed to teaching members of the group any aspects they do not understand. This process creates mutual responsibility and team spirit, which lead to enthusiasm and motivation to learn.

Box 4.13. **The MOOC programme in the Israeli education system** *(cont.)*

The reversed classroom means students prepare for learning, so that the scholastic material in the course is learned at home. At the same time, the students are in contact through social media (WhatsApp, Facebook, shared files), joining discussions and studies during the week. They meet once a week with the teacher. In the classroom, there are in-depth discussions and brainstorming sessions about the scholastic content.

The Ministry of Education began its MOOC programme based on this integrated model in 2014, with 14 classes studying two international MOOC courses, in astronomy and robotics, and 83.5% percent of participants completed the courses. In 2015, 20 classes participated in the programme and the number of courses was increased to 7, with 85% of students completing the courses.

In 2016, the programme was expanded to 46 classes and some 1 200 students, studying 12 courses: 1) Biology – The science of happiness, nutrition and eating disorders; 2) English grammar; 3) History – Beginnings of Zionism; 4) Python programming language; 5) Astronomy; 6) JAVA programming language; 7) Introduction to the history of the Holocaust; 8) Introduction to renewable energy; 9) How to learn maths; and 10) Robotics.

The Ministry of Education translated a number of courses into Hebrew and allocated an area for managing the study. Teachers who assisted the students participated in training seminars and received individual supervision from the Education Cities Network, which trained them in the integrated model, HOW2MOOC. Teachers helped the students taking the MOOC courses and taught them 21st century skills, including cognitive development, team work, mutual support, self-management, assuming personal responsibility for learning, intelligent and relevant use of digital means and social media.

In 2017, the number of classes participating in the programme increased to 500. Currently, a group of teachers who are experienced at assisting students on MOOC courses are being trained in the Becoming MOOCsters programme to become supervisors of new teachers joining the programme.

Another channel used in the programme in 2016 – math teams, teaching 5-study unit level mathematics

1. Maths teachers used the team model to teach mathematics. They were trained to use the model at training seminars and received individual supervision in implementing the model in the classroom.
2. Standard textbooks and teaching materials were made available to the teachers. An Etgar 5 environment was developed based on the materials developed at the virtual high school and various materials online.
3. The classes learning in the maths teams format were: Grade 9 – Excellence or accelerated track A, Grade 10 – 5 study units-maths, Grade 11 – 5 study units-maths.

In total, 62 teachers, 39 schools, 101 classes and 2 176 students participated in the programme.

Last month, there was a 5-study unit math matriculation exam and the exam results will be used to examine the relationship between the programme and the students' achievements, their sense of competence in studying accelerated maths and to gain insights into the programme.

Source: Ministry of Education, Israel.

With less than five years of history, it is too early to determine the success or failure of MOOCs. MOOCs are still seen as having a number of vulnerabilities: the difficulty of granting credits and degrees, the sustainability of the business models, low completion and high drop-out rates, and the pedagogical model prevalent in a lot of the courses. Yet, many MOOC platforms are seeking to improve on these critical issues. Even the most established providers continue to change their services to reach a broader audience and ensure long-term financial sustainability. Udacity, the first MOOC provider, was also the first to shift from a student to a corporate-oriented model, whereas EdX has kept its focus on their original mission of expanding access to knowledge.

While MOOCs and other online means of delivering learning have not yet revolutionised education systems, their growing popularity is provoking a lot of debate. They have raised many expectations about the groundbreaking opportunities they could create, as well as uncertainties about their limitations, risks and potentially disruptive effect on the current higher education model.

Box 4.14. **Online private tutoring project in Israel**

Background: High percentages of high school and middle school students receive private tutoring in Israel. A survey indicates that the top priority subjects for tutoring are mathematics, English and Hebrew grammar. Due to the cost and the availability of teachers in the periphery, such private tutoring creates gaps in scholastic achievements based on socio-economic background.

The project: The Ministry of Education operates an online learning and tutoring centre which provides assistance, free of charge, to any student who wishes to improve his or her scholastic achievements. The system offers two types of service:

- Private lesson – 55 minutes – scheduled in advance by the student with the teacher, and taking place in a virtual classroom on the date scheduled.
- Immediate assistance – 2-minutes – students join an online queue and receive immediate assistance in the virtual classroom

The project was piloted during the second half of the 2015/16 school year, during which it operated in a limited manner for students in Grades 10 -12 in mathematics and English. The project recruited experienced teachers to run the scheme as well as volunteers and outstanding students.

Data on use:

- approximately 2 200 students used the service
- 153 schools nationwide actively participated in the project
- 2 500 short study sessions were held, for 20-25 minutes each session
- 2 300 60-minute private lessons were given.

Feedback received from students who used this service was very positive – the teachers received high satisfaction scores.

After the successful pilot, the project is preparing to expand. During the 2016/17 school year, the range of subjects will also include Hebrew grammar and the service will be offered to middle school students as well as high school students (Grades 7-12) nationwide – with priority given to those on the social, cultural, and geographic periphery.

Source: Ministry of Education, Israel.

Key messages for innovation policies in education

A thorough look into some of the most promising pedagogic models integrating ICT reveals the huge potential of digital technologies to improve teaching and learning. Educators should consider adopting these innovative technology-supported pedagogic models to improve outcomes, including the development of higher-order thinking skills, and to expand the range of learning opportunities available to students:

- Technology-supported models such as models based on gaming, online laboratory experiments and real-time formative assessment can increase students test scores and conceptual understanding as well as enhancing students' creativity, imagination and problem-solving skills.

- Technology-supported education can also widen teachers' and students' teaching and learning opportunities. For instance, online laboratories (remote or virtual) provide a wider range of experimentation and learning-by-doing than would be possible without technological support.
- Technology also increases possibilities for intercultural collaboration, providing students with the opportunity to experience the sort of international collaboration, that is common in today's professional environments.
- Finally, technology facilitates assessments that allow teachers to monitor student learning as it happens and adjust their teaching as required and identify the skills students need to acquire in a more comprehensive way than would otherwise be possible.

The challenge of adopting these models is more to do with integrating new types of instruction, rather than overcoming technology barriers. Their adoption by teachers is most likely to be sustained and effective when there is adequate support from policy makers. The efficacy of technology-supported models comes largely from the pedagogy that it supports: teachers need the resources and understanding of how to use them. Real-time formative assessment may allow teachers to observe students' learning in real time, but they still have to use this information in their teaching. Experiential learning is most likely to improve students' understanding and skills if teachers encourage them to repeat their experiments and provide them with a robust scaffolding to understand them.

In order to meet this pedagogic challenge, teachers need adequate professional development. A common barrier to adopting new teaching models and resources is lack of formal teacher training, peer learning and more. Teachers also simply need time to integrate new technology-enhanced educational models into their pedagogy.

While success is driven by pedagogy, technology-supported models generally require a certain level of equipment although mainly relatively low-cost and familiar devices such as computers, tablets or mobile phones, with Internet connections.

Another critical success factor is the availability of a critical mass of teacher-friendly educational content and resources. Many digital resources are also freely available to teachers: these include simulations in virtual environments (remote or online laboratories, games) and software for real-time formative assessment.

Context also counts a great deal when projects are scaled up: innovations must be responsive to local needs and educational structures.

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Innovating Education and Educating for Innovation
The Power of Digital Technologies and Skills

Chapter 5

Markets and innovation in the education industry

The private education resource industry is one potential source of innovation in the education sector. This chapter outlines the results from a study of the market structure of the education industry covering 14 countries. The chapter reports its findings on 1) the size of the market, segmented where possible by levels of education; 2) the number of firms and degree of market concentration; 3) the market leaders; and 4) the level of investment by those market leaders into research and development.

The chapter also considers how the information available about the education resources sector could be improved and the role of policy makers in encouraging greater innovation in the sector as part of a wider innovation strategy for education and training.

Introduction

As discussed in Chapter 1, innovation in education will be essential to ensuring a flexible, modern education system, capable of driving innovation in the economy and society. As in other sectors, education should benefit from a strong innovative industry developing resources and devices that improve its effectiveness and efficiency. What do we know about innovation in the education industry? Is it as dynamic as it should be? What role(s) do policy makers expect and encourage the education industry to play when defining education innovation policies? And more specifically, do sectoral innovation policies for education include business-driven innovation?

All these questions are difficult to answer given the dearth of information about the education industry – here considered as the generally for-profit businesses that sell education resources, services and tools to schools, universities and individuals, rather than the private schooling, university and training sectors that deliver education to individuals. This chapter proposes a first exploration of the market structure of the education industry, the current role of private firms in education research and development (R&D) and innovation, and the implications for governments. It is based on a study[1] covering 14 countries: Australia, Canada, Denmark, Finland, France, Germany, Hungary, Italy, Japan, Mexico, the Netherlands, Spain, the United Kingdom and the United States.

The aim of the study was to estimate, for a certain point in time (2010): 1) the size of the market and its different segments by level of education and type of product (textbooks, tests and examinations, electronic devices and software); 2) the number of firms and the degree of market concentration; 3) those leading the market and its various segments; and 4) the level of expenditure by market leaders on research and development (R&D) and marketing.

Size and structure of the education resource industry

Estimates of the size of the "education resource industry" in 2010 varied from about USD 50 million in Denmark and Hungary to almost USD 12 billion in the United States. These estimates refer mainly to the education publishing industry; information about other subsectors was difficult to identify. Moreover, including non-publishing sectors made the comparability of the data more problematic. The data from individual countries may be based on different definitions of the industry, depending on the sources and the countries. However, where information is presented at different points of time, the market boundaries remained stable over that period.

Publishing seems to be by far the largest segment of the education industry, but the industry also develops electronic devices and assessments, which can form a sizable market. There are also other activities such as education consultancy. While for-profit education and training services can also be seen as part of the industry, they were excluded from our study. They would arguably deserve their own category rather than being included under "other activities". They would also most likely be much larger than the education resource industry in countries where private education services are moderately developed.

Some values also had to be estimated: for example, for Japan, the figure corresponds to the market for textbooks sold to schools in the pre-primary, primary and secondary sectors. One source suggested that education is about 10% of the overall book market in Japan, which would amount to about USD 670 million in 2013, but the information could not be verified. In the Netherlands, the market is limited to the pre-primary, primary and secondary levels. In Canada, France, Germany, Mexico and Spain, information is based on information about general publishing and corresponds to the market for educational books to the general public (including schools). In the United States, the market covers all levels of education, and other types of resources than simply published ones. The most comparable value to other countries is the educational book market, which was estimated at USD 23 billion in 2010. Several market researchers use a broader definition to estimate the value of the education resources sector in the United States, but the values are so different that it is more prudent to limit the boundary to publishing activities.

Information about how the overall total value of the market in Finland and Japan was split between publishing and electronic devices, showing that publishing accounted for 96% of the total in Finland and 99% in Japan. This information should be interpreted with caution as the estimates are based on the publishing sector and, in the case of Japan, limited to the school market.

Between 2000 and 2010, the education resource market grew in Canada, the United States and perhaps in the Netherlands. However, the market shrank over the same period in Australia, Denmark, Finland, Germany and Spain. This decrease continued until 2015 in some countries, for example in Germany and Spain.

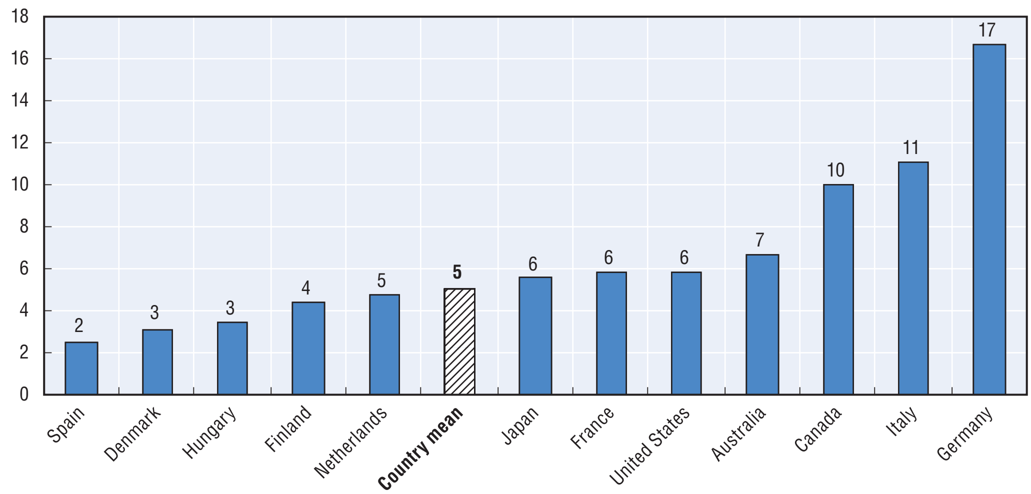
It was difficult to acquire information about the education levels targeted by the education industry. Finland has data from 2005 and 2010, breaking down market value into lower secondary, higher and other education, with the bulk of the market concentrated at the lower secondary level (61% in 2010). The value of the education resources market for each level of education reduced at a similar rate to the reduction in the value of the education resources market in Finland overall.

In France, the bulk of the school textbook market was in secondary education in 2011 (47% of the schooling market and 28% of the overall education market). A generous definition of the higher education market made it worth 40% of the education book market in France. In Germany, school books represented about 41% of the education publishing market in 2014, with higher education and professional books making up the rest. In 2013, the textbook market for primary and secondary education represented 46% of the education book market in Mexico and 33% in Spain. In the United States, the textbook market for primary and secondary education was more or less the same size as the higher education market in 2010, each accounting for about 23% of the overall educational book market. Professional books made up the rest of the market.

The data available indicate that the educational resources industry is moderately to highly concentrated in most of the countries, suggesting that there is relatively little competition (Figure 5.1). The Herfindahl-Hirschman Index (HHI) indicates that Denmark (0.32), Hungary (0.29) and Spain (0.41) have high levels of concentration whilst moderate levels are observed in Australia (0.15), Finland (0.23), France (0.17), the Netherlands (0.21) and the United States (0.17). In contrast, low levels of concentration were observed only in Canada, Germany and Italy.

Figure 5.1. **Concentration of the education publishing industry, 2010**

Inverted Herfindahl-Hirschman index (HHI)



Source: Vincent-Lancrin, S., A. Atkinson and K. Kärkkäinen (forthcoming), "Market structure and Innovation Amongst Education Publishers", in Vincent-Lancrin, S. (Ed.), *Business-driven innovation in the education sector,* OECD Publishing, Paris.

Another way to present the market structure is to consider the number of firms at different market shares as well as the overall number of firms. Some of the countries covered in the study have a clear oligopolistic market structure, while others have many more firms. Our data indicate that in Canada, Germany, Italy and the United States no single firm had a 20% share of the market but in Denmark, Finland and Japan, one firm had at least 40% of the market share and in Spain one firm was responsible for over 60% of the market. The data available thus suggest a certain concentration of the market, with on average four publishers sharing 60% of the national education market.

In an oligopolistic market structure, innovation can come from the few companies sharing most of the market. It can also come from the smaller firms if they are entrepreneurial and investing in the development of new products or services. Typically, smaller firms developing an innovation will either grow or be bought by the larger ones interesting in acquiring the innovations they have developed. In the countries covered, there are both a varying number of firms in the market and also at its margin. Whilst the education market seems dominated by a small number of publishing firms, there seem to be many firms operating in most countries. These may be smaller entrepreneurial firms developing innovations, or they could be firms operating in niche markets without a particularly strong innovative profile. This would need to be assessed for each country.

The innovation role of market leaders

The market leaders within the education resources industry can be identified by looking at the companies with the largest share of the market in each of the countries being studied. The market clearly has a global dimension, with some market leaders, such as Pearson Education, being prominent in more than one country, whilst others, such as Tammi Learning, are partially or wholly owned by firms in other countries. Whilst some multinationals are active in over 100 countries, others focus on markets that share a common language (particularly English or Spanish amongst the countries studied). Judging by the list of competitors listed in various company accounts, the world leaders in this field appear to include the Pearson Group, McGraw-Hill Companies, John Wiley & Sons, Reed Elsevier (Relx Group), Oxford University Press, Random House, Scholastic, Simon & Schuster, HarperCollins, Holtzbrinck, Hachette Livres, and Santillana.

The international market is also subject to many mergers and acquisitions. This means that the ownership of many of the market leaders has changed over time, as firms seek to enter new markets or change their portfolios. For example, WSOY (Werner Söderström Ltd) in Finland has been part of the international media company Bonnier Group since 2011 but was previously part of Sanoma.

Formal agreements between companies also shape the global market. Cengage, for example, discloses an operating agreement for Nelson in Canada, giving Nelson the exclusive right to adapt, customise and translate Cengage publications.

Across the countries in this study, the market leaders have a range of legal structures, including private, public and not-for-profit. This variety of firm types is also evident in some countries, such as Australia, Canada, Finland, Germany, the United Kingdom and the United States, whereas in other countries the market consists only of private companies. In Mexico, one of the major actors is a government organisation.

The size of some of the multinational groups operating within these countries is also striking. They are sometimes much bigger than the entire national market of some countries. With its turnover of USD 7 billion in 2014, Pearson is the foremost multinational publisher in the world and the foremost specialised educational multinational company. It is clearly a major actor in the global education industry. Several of the world's largest publishing companies also have a strong education specialisation and tend to be one of the market leaders in their country. Relx Group (Elsevier) was the third largest publishing company in the world in 2014 (USD 5 billion of turnover) and one of the market leaders in the United States; Hachette Livre, the 6th publisher leads the French market; Holtzbrinck, the 7th, a leader in Australia; Grupo Planeta, the 8th, in France; Cengage, the 9th, in Australia; McGraw Hill Education, the 10th, in the United States, Canada and Australia. Japan is the only exception, as the largest Japanese publishers in this list do not seem to be major players in the market for education books and resources.

The level of investment by big firms in innovation is generally reflected in their expenditure on R&D or marketing. However, there is no international standard for reporting R&D, and companies do not typically report marketing costs as a separate expense. We have extracted information on intangible assets, pre-publication costs or R&D from company accounts where possible but this information is typically from consolidated accounts, which for multinational companies span across countries and sectors. Contact with the companies listed did not result in more refined data.

Information about the value of intangible assets suggests that less than 10% of the total assets held by the majority of large publishing and media groups relate to anything that might indicate some form of research or development. Amortisation of these assets is often less than 1% of total expenditure (before tax). The few companies or groups that mention research, development or pre-publication costs do not appear particularly different from the others in this regard. This does not provide policy makers with sufficient depth of information to know either the scale of current R&D activities or the innovative potential of the companies. It also provides no information about the level of R&D within a particular market.

Existing data about the expenditures in R&D in the publishing sector pointed to a rough estimate of R&D intensity of 1.7% of all expenditure in 2010, including expenditures in software publishing which are much higher than in the book sector. With the exception of Austria, Italy and the United Kingdom, the R&D intensity of the publishing sector is higher than in the service sector. It is also consistently much lower than in the manufacturing or pharmaceutical sector. Market leaders' published accounts indicate that innovation-related expenditures may be in line with the sector as a whole, and should not necessarily be considered to be particularly low.

However, the mere fact that published accounts do generally not report R&D or innovation-related expenditures shows that investment in innovation is not considered a major asset or competitive advantage in the sector, one that could potentially attract investors.

Improving the knowledge base

Why is it so difficult to get reliable information about the education resources sector?

The first reason is that there has been no international endeavour before to map the education market and its segments. This means there are few resources to build upon, and in particular no common market boundaries used by the different actors when they publish accounts or review the education industry. This limitation could be overcome by integrating this topic into the regular collections of education data (or industry data, for that matter). Our study proposes a few categories into which such data should be collected.

The second reason is that the education resource industry is not always perceived as a specific industry in its own right. It is more often seen as one component of other industries such as publishing or software design. For example, education represented 15.5% of the publishing market in France in 2011, and about 10% of the German publishing market. While this is a sizeable market, one can understand that it does not appear to be a distinct market to generalist publishers themselves. Typically, electronic devices or software in education tend to be more applications of technologies developed for other markets than specialised ones, even though this trend may be changing (Foray and Raffo, 2015). This lack of "identity" or specialisation is also reflected in a lack of dedicated professional associations for education resource developers or producers. Such associations exist in Europe (e.g. ELIG, (EuropeanLearning Industry Group)) or in the United States though (e.g. Education Industry Association), but even when they produce industry data, the data produced are not comparable.

Whilst it is possible to estimate the education market structure in most countries, stakeholders within the educational resources industry appear to be reluctant to share information about their turnover, market share and R&D activities. There might be some mistrust about how this information could be used, especially in a sector where many businesses are not listed on the stock market and have limited public obligations. Policy makers can typically confirm that some publishing companies are plausibly market leaders in their country, but they do not seem to have much information about their domestic education resource industry either. Education ministries typically have no responsibility for providing incentives to education publishers to produce innovative resources: instead this is the responsibility of ministries of finance or economic affairs, for which education is just one sector among many.

Much information which could not be gathered through this research could potentially be obtained through other channels, perhaps even via a small-scale survey targeting the firms identified. Such a survey could also be used to gain a better idea of how big firms perceive the education market and its distinctive features, to what extent and how they invest in R&D and innovation, and under what circumstances they would be ready to invest further.

The OECD could support international efforts to improve information sharing in this area. The first "industry summit" that took place in Helsinki in October 2015, bringing together ministers and leaders of the education industry, aimed to start such discussions. Such summits could facilitate dialogue and information exchange, including the level of innovation within the industry and discussion of the problems that governments are seeking to address within the education sector. Other working meetings based on responses to the small-scale survey mentioned above could enable a conversation about ongoing innovations, to tackle barriers to innovation and the lack of available data.

Implications for policy makers

Ultimately, the reason why education policy makers should be interested in the size, market and innovation intensity of the education industry is because innovation policies should partly build on the business sector to generate and disseminate innovation – as is the case in any other sector of society.

The data reported in this study indicate that the education market (or of some of its submarkets) is growing in some countries. This could potentially encourage new entrants and innovation. Where the market is shrinking in value, it may be worth exploring the reasons for this reduction and checking to see whether the decline has resulted in a reduction in innovation. Sometimes, this may be due to the substitution of print resources for digital resources. In other cases, this may correspond to changes in regulation or in the purchasing behaviour of public and private actors. Keeping an eye on these trends can help ensure that barriers to entry are low, that current levels of competition are conducive to innovation, and that public policies do not have an adverse effect on innovation in the industry. Otherwise, certain countries may miss out on innovative products and delivery methods being developed elsewhere.

The small number of countries with data by education level highlights the value of knowing where growth is occurring. It may be that the increased interest in lifelong learning and the need to refresh or renew skills is creating a new market in education resources for adults outside of formal learning environments. A new, emerging market would be expected to be highly innovative, and may generate R&D that could be applied in other levels of education. It is also clear that schools are an important but not a dominant segment of the larger market for education resources. Individuals seem to be a major source of demand.

The occurrence of the same companies as market leaders in different countries clearly highlights the need for national policy makers to have an international perspective. In particular they need to consider where the power and business interests lie within their domestic market, how they align with policy goals, who the new market entrants and innovators may be, and how government resources can be used to stimulate innovation that will benefit the national education system (Box 5.1).

Box 5.1. **Policy-relevant research questions on the innovation role of the education industry**

Policy makers keen to stimulate innovation in the educational publishing industry need to consider both the data and the gaps in their knowledge to decide how to address the following questions:

1. Is the market structure of the education resources industry a result of the types of production of the sector?
2. Does the market structure reflect demand for education products, and especially public demand?
3. Are different segments of the education resources market structured differently?
4. Do big firms have enough incentives to develop innovative products that could potentially improve the quality and effectiveness of the education sector?
5. Can the smallest newly-established innovative firms within this market develop and grow in their current environment?
6. Is the structure of the educational component of the publishing industry similar to other segments of the education market?
7. Can education policy makers shape the incentives to innovate through new regulation, public procurement or targeted policy measures for the sector? Should these policies be differentiated depending on the segments of the market?

The study of the education industry matters if fundamental questions are to be answered. For example, the lack of explicit reporting of R&D and the apparently small innovation-related expenditures may ring alarm bells for policy makers. It is possible that education would benefit from more private investment in R&D and in innovation to improve its effectiveness and efficiency. It is also possible the current low level of investment may be adequate given the nature of innovation in the industry. Does the oligopolistic structure of the market lead to low incentives to innovate because of excessive market power? Or, on the contrary, is this structure necessary given the nature of the production process in the sector? With no answer or better understanding of these questions, it will be difficult to stimulate or ensure a strong, innovative education industry serves the education sector and the lifelong learning of citizens.

In the education sector, a too-visible collaboration between public authorities and the private sector is sometimes perceived as problematic. However, most curricular reforms or expected changes in teaching practices ultimately benefit from this kind of collaboration as it is generally private companies that produce textbooks and pedagogical resources for teachers. On average, over 60% of students have teachers who use textbooks as a primary resource for their instruction (OECD, 2014). Ensuring that the education industry has enough incentives to develop new or significantly improved resources for teachers and students should certainly be part of education policy, and, more precisely, of an explicit innovation policy for education and training.

Key messages for innovation policies in education

Policy makers typically view education industries as providers of goods and services, often technology-based, to schools. They tend to dismiss the fact that innovation in education is also changing the environment in which schools are operating. Technology-based innovations tend to open up schools and learning environments in general to the outside world, both the digital world and the physical and social environment. At the same time they bring new actors and stakeholders into the educational system, not at least the education industries with their own ideas, views and dreams about what a brighter future for education could hold.

Convincing schools and education systems to treat industry as a valuable partner is still in many cases a very sensitive issue. Fears about or ideological objections to a perceived "marketisation" or privatisation of education, or outright anxieties about the displacement of teachers by computers, often endanger a potentially fruitful dialogue. The fact that the global education industry is a largely unknown entity – in contrast to the medical or paramedical industries in the health sector, for example – further adds to the difficulty.

As a first step, governments should get to know the education industry, both locally and internationally. Market research is not only useful for the procurement goods and services, but also to get a better idea of potential partners. That was exactly the purpose of this chapter: to start the market research and improve the knowledge base about the education industry.

Note

1. A more extensive report is available upon request and will be published in due course.

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Innovating Education and Educating for Innovation
The Power of Digital Technologies and Skills

Chapter 6

Business-driven innovation in education

Innovation should offer the education sector the means to close the productivity gap by disseminating new tools as well as new practices, organisations and technology. This chapter considers why educational scientific research has done little to create a body of practical technical teaching know-how or improve practices in the classroom. It then uses patent data to analyse the state of technical innovation in the educational support market, and identifies the emergence of a specialised educational tools industry which may help to disseminate the results of scientific research into education. Although there are barriers to small innovative firms in the educational market, and patents can have a damaging effect on innovation within the classroom, it appears that the most promising markets for new educational tools lie outside the public school system – in tertiary education, corporate training and individuals undertaking lifelong learning.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

This chapter analyses business-driven innovation in education by looking at education-related patents. It first draws a picture of the challenges for innovation in the formal education sector, which suffers from poor knowledge ecology: research in the field has barely any impact on core teaching and administrative practices. It then turns to a common indicator of innovation: patents. In the case of education, patents typically cover educational tools. An analysis of education-related patents over the past 20 years shows a clear rise in the production of highly innovative educational technologies by businesses. While this increase in educational innovation may present new opportunities for the formal education sector, the emerging tool industry currently targets the non-formal rather than the formal education system. Finally, the chapter briefly discusses why business entrepreneurs may be less interested in the market of formal education.

A first look at innovation in education

Educational innovation is the act of creating and then disseminating new educational tools as well as new instructional practices, organisational forms and technology. Although innovation is not research, it is often based on research and advances in knowledge and consists in changing processes and practices in order to improve the quality and productivity of the service which is delivered.

Many years ago, William Baumol introduced an interesting distinction between progressive and non-progressive sectors. Non-progressive sectors are those in which productivity growth is limited, very sporadic and far slower than in the progressive sectors of the economy (Baumol and Bowen, 1965; Baumol, 1967). This productivity gap between the two kinds of sector gives rise to "Baumol's disease" (or "cost disease"). Education has always been considered by experts as a paradigmatic example of a non-productive sector (Roza, 2008; Hill and Roza, 2010). Creating an education sector in which valuable innovations are constantly generated and efficiently used and managed is a major challenge to "re-invent" public education and find solutions to this so-called disease

In education, changes are often proposed outside the schools and then disseminated into them by reformers. The source of these changes is thus external reform rather than grassroots innovation. Such "outside-in" logic probably reduces the chances of the successful adoption, implementation and institutionalisation of new practices. Policy makers may be frustrated by the failure of such reforms to endure and displace poor practices. An alternative approach could be to consider innovation as a decentralised way to use new knowledge and information (both from research and current practices) in order to identify problems and generate solutions. Because people are motivated to disseminate knowledge and solutions that they have themselves created, this opens natural, but under-used, channels for easy dissemination of new ideas (Foray and Hargreaves, 2003). These channels include repositories of open educational resources that are generated and shared by teachers and other educators (OECD, 2007a).

Last but not least, it is useful to stress that one of the major challenges associated with the study of educational innovation is the lack of data. Studies of technological innovations traditionally focus on research and development (R&D) spending and patents. These measures are unlikely to be satisfactory in this context, although this chapter does analyse patent data to a certain extent below. Recent work at the OECD Centre for Educational Research and Innovation (CERI) provides new data on educational innovation and proposed different ways to collect innovation data in education (OECD, 2014). Systematic data collection would help better understand educational innovation and improve innovation policy in the education sector.

A difficult science with poor links to practice

Experts often describe the educational sector as suffering from a lack of innovation and a structural inability to improve instructional technologies and practical knowledge and know-how about pedagogy at the same rate as in other sectors. Even though, as Chapter 1 discussed, there is more innovation in education than most people believe (OECD, 2014), most criticism about the innovation process in education seems to be still relevant:

> Consider the efforts to develop more effective educational practices in schools: even if we do know more about educational practices than we did previously, knowledge creation in this domain has been slow and there have been severe difficulties in diffusing "new and superior" knowledge *(Nelson, 2003)*.

The main problem is the difficulty of developing a science which can illuminate practices and provide guidance to their systematic improvement (Foray, 2001, 2006). Formal research and development (R&D) has largely remained of secondary importance both for the training of people and for the generation of useful innovation. What Nelson and Murnane wrote more than 20 years ago on education is still by and large true: educational R&D is very weak in producing practical solutions: "[In the education sector,] R&D should not be viewed as creating 'programs that work'; it only provides tidy new technologies to schools and teachers. It is thus a mistake to think of educational R&D in the same way as industrial R&D" (Murnane and Nelson, 1984).

Only rarely does educational R&D generate knowledge of immediate value for solving problems and developing applications. While social science theory will naturally still continue to contribute to education, the goal of this kind of research is not to provide and develop a repertoire of reliable practices and tools to solve immediate problems that teachers meet daily in their professional life: "For novice teachers, practical problems in classrooms are not usually perceived to be solvable by drawing upon the psychology of education or child development that have been studied in universities" (Foray and Hargreaves, 2003).

This problem of the weak link between science and the improvement of practices is crucial since it has a negative influence on both the supply of and the demand for research. Weak supply and insufficient demand combine to create a fundamental inertia in the system.

Three factors explain the limited role science plays in illuminating practices in education:

First, on the supply side, educational science is just very hard to do. As Berliner (2002) wrote about educational research, "we do our science under conditions that physical scientists would find intolerable". Compared to designing a bridge, the science to help change schools and classrooms is harder to do because the context cannot be controlled and the difficulties of generalising across contexts reduce the ability of any research finding to illuminate a body of practices. There is indeed an educational science but it is nothing like the kind of applied science or engineering discipline which could develop a body of knowledge and techniques that could illuminate educational practices.

Second, on the demand side, most practitioners who are (or should be) involved in the improvement of teaching practice do not believe that the educational problems they face in the course of their professional life can be solved by inquiry, evidence and science (Elmore, 2002). For example, they do not believe that it is necessary to have a developmental theory of how students learn content and how pedagogy relates to the development of knowledge and content. Weak incentives for teachers to use research are rooted in deep cultural norms; teachers tend to believe that teaching is an individual art founded on natural quality, inspiration and talent, and not a set of competences acquired over the course of a career (Elmore, 2002). Because of this cultural norm, it is very difficult to make a case for knowledge management, building databases of evidence on "what works" and encouraging teachers to behave like engineers by searching for solutions to problems in case books. " Teachers are primarily artisans, working alone in a personally designed environment where they develop most of their skills by trial-and-error tinkering. In short, they learn to tinker, searching pragmatically for acceptable solutions to problems their 'clients' present" (Foray and Hargreaves, 2003; see also OECD, 2004, 2007b).

Finally, there is a general lack of incentives to codify technical knowledge and know-how and the resources allocated to codification are weak. Numerous practices remain tacit; not explicated and not articulated, invisible and difficult to transfer:

> There is no more in education than a weak equivalent in the field of pedagogical knowledge to the systematic recording and widespread use of cases found in surgery or law and the physical models in engineering and architectural practice. Such records coupled with comments and critiques of experts allow new generations to pick up where earlier ones left off. *(Foray and Hargreaves, 2003)*

Education lacks some important mechanisms to support the accumulation and progression of knowledge and to materialise any potential spillovers: "The beginner in teaching must start afresh, uninformed about prior solutions and alternative approaches to recurring practical problems. What student teachers learn about teaching is intuitive and imitative rather than explicit and analytical" (Foray and Hargreaves, 2003).

When excessive stocks of knowledge are left in tacit forms, this makes them more costly to locate, appraise and transfer. One result may be excessive insularity and waste of resources resulting in the underuse of existing knowledge. This may in turn create private and social inefficiencies.

Translating increasing pressure over performance into innovation

To put it in Nelson's words, in most sectors the key to success in advancing technical knowledge has been to design practice around what is known scientifically. As discussed above, this process is not operating well in education, meaning that policy makers, industries and the society as a whole are asking schools to make improvements in the absence of strong technical core. As Elmore puts it in a provocative way:

> Consider what would happen if you were on an airplane and the pilot came on the intercom as you were starting your descent and said, "I've always wanted to try this without the flaps". Or if your surgeon said to you in your pre-surgical conference, "you know, I'd really like to do this way, I originally learned how to do it in 1978". Would you be a willing participant in this? People get sued for doing that in the "real" professions, where the absence of a strong technical core of knowledge and discourse about what effective practice is carries a high price. *(Elmore, 2002)*

The problem is not so much that schools and managers lack incentives to improve educational practices and technologies. These incentives are probably less powerful than in other sectors, but increasing pressure over school performance, channelled through higher standards and accountability, is also increasing incentives. The problem rather lies in the way practitioners, teachers and administrators try to respond to these incentives and pressure – the failure to translate such pressures into innovation, improved practices and the development of instructional know-how and technologies. Practitioners do not try to improve practices by relying on a strong technical core of knowledge that should be available in case books and databases. Instead, they respond to the increased accountability by changing structures; but changing structure does not change practices. As Elmore (2002) argues forcefully, people and schools put an enormous amount of energy into changing structures and usually leave instructional practice (innovation) untouched.

Patents in educational and instructional technologies

A small (innovation) explosion?

A quick look at patent data provides us with a more optimistic view of innovation in the education sector, and in that respect concurs with other data on innovation in education (OECD, 2014).

Following Foray and Raffo (2009), any patent filed under the G09B IPC subclass could be considered educational or teaching related. This subclass is defined as “educational or demonstration appliances; appliances for teaching, or communicating with, the blind, deaf or mute; models; planetaria; globes; maps; diagrams”. It covers simulators regarded as teaching or training devices, which is the case if they give perceptible sensations similar to the sensations students would experience in reality in response to actions taken by them; models of buildings, installations, or the like. But it does not includes simulators which merely demonstrate or illustrate the function of an apparatus or of a system by means involving computing, and therefore cannot be regarded as teaching or training devices; components of simulators, if identical with real devices or machines (see Box 6.1 for examples of recent patent filings). However, because it includes technologies related to maps, the category includes patents related to the development of global positioning systems or of using maps for smart cars – and thus somewhat overstates what would commonly be seen as education technologies, machine learning aside.

While their number remains relatively low, patent applications filed under the Patent Cooperation Treaty (PCT) in the domain of educational and teaching technologies have increased threefold since 2000 (Figure 6.1 Evolution of the world’s education-related patents by priority year, 2000-14). As a share of total patents, the trend is flat, which shows that technological innovation in the sector is growing at the same pace as the average.

This growth is not simply explained by large companies trying to apply their existing technologies to the education sector; a population of small firms have emerged specialising in the development of technological solutions to educational problems and issues. This is apparent by the entrance of new firms (Figure 6.2 Firms filing education-related patents, entry and technological concentration, 1990-2004a), but also in the declining (technological) concentration revealed by different indicators. Figure 6.2b shows that concentration in the sector – expressed by the technological shares held by both the top four and by the top ten firms – has steeply declined between 1990 and 2005. While this analysis could not be updated for this chapter, there is no reason to believe that this trend has reversed. The inverse Herfindahl-Hirschman Index (HHI), an indicator of the oligopolistic nature of industries, furnishes a similar picture, showing that the technological concentration has been reduced from around 30 to 60 “ideal” firms. However, all three indicators suggest that this de-concentration might be slowing down or, if we consider the Herfindahl-Hirschman Index, even regressing. In any case, these preliminary results suggest the emergence and consolidation of an industry specialised in the production of educational and instructional tools and knowledge with strong roots in new information technologies. A large part of this industry is made of small and specialised firms.

Box 6.1. **Examples of education-related patents.**

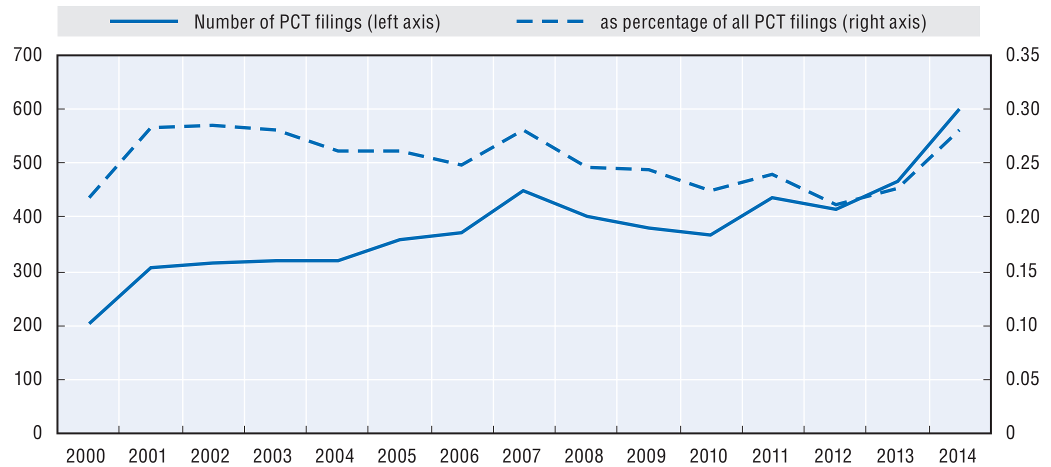
Education-related patents are typically filed for products or devices that will be used in a training or education context, for training processes related to a specific set of skills (such as music, medicine, foreign languages or reading), or for a general method that can be used in multiple educational settings. While many patents typically build on advances in information and communications technology (ICT) and propose some sort of simulation of real-life practice, patents may also be filed for objects or devices or tools that are not primarily ICT-based: card games to learn languages; mock-ups of chests, infant torsos, jaws, blood vessels or organs designed to practise specific medical techniques; teaching devices for some specific mathematical question, for example a device around Pythagoras' theorem demonstrating it arithmetically, geometrically and algebraically; or simply a ruler to facilitate the learning of reading.

A list of some of the titles of education-related patents filed in 2014 illustrates the variety:

- Human torso and simulator system for training in surgical
- Computer-implemented training of a procedure
- System and method for enhanced teaching and learning proficiency assessment and tracking
- A dummy instrument for use in a simulator
- A force feedback device
- System and method for electronic test delivery
- Musical notation systems and methods
- System and method for performing virtual surgery
- Device, method and graphical user interface for a group reading environment
- Detecting aberrant behaviour in an exam-taking environment
- Collaborative learning environment
- A device for colour matching a cosmetic composition with the skin shade of a person
- A method for communicating and ascertaining material
- Importing and analysing external data using a virtual reality welding system
- Systems and methods providing enhanced education and training in a virtual reality environment
- Device and method for simulating a transportation emergency
- Virtual reality and pipe welding simulator and setup
- System and method providing combined virtual reality arc welding and three-dimensional (3D) viewing
- Information processing device, and information processing method
- Devices, methods, and systems for high-resolution tactile displays
- An image capture device foldable stand
- System for characterising manual welding operations
- Methods and systems for identifying and securing educational services
- Fire extinguishing training device
- Computer-implemented method for facilitating creation of an advanced digital communications network
- Toothbrush training system
- System and method for providing a game show with a specialised voting procedure
- Wireless immersive simulation system

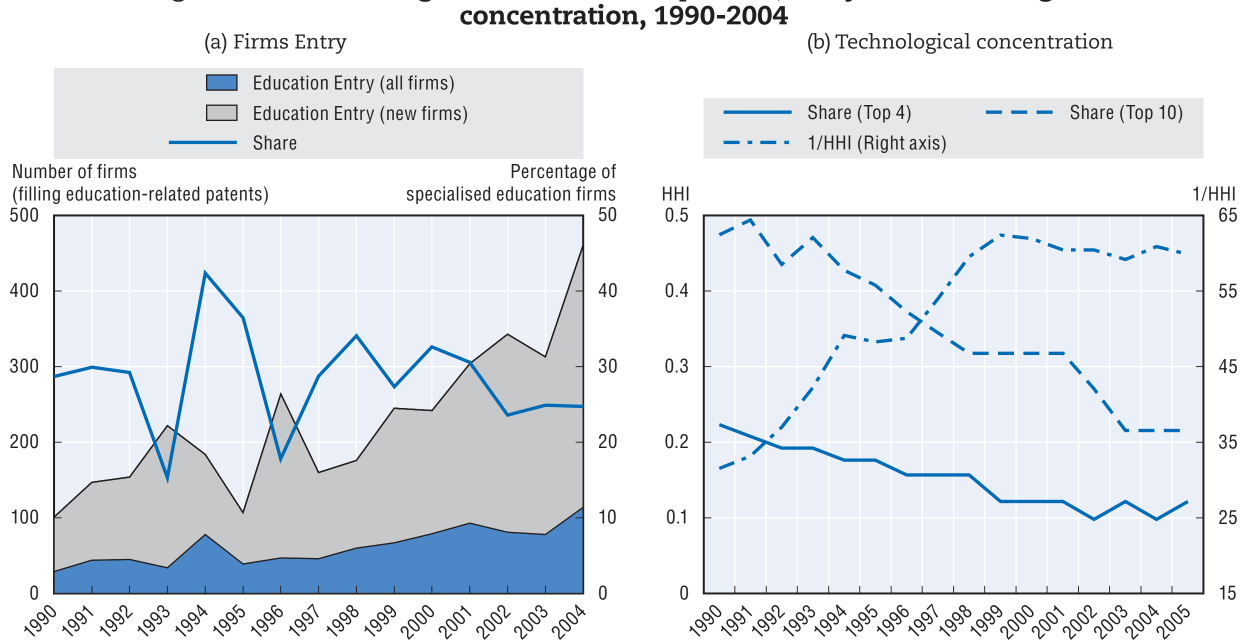
Source: World International Property Organisation,(WIPO) *http://www.wipo.int/portal/en/*.

Figure 6.1. **Evolution of the world's education-related patents by priority year, 2000-14**



Source: Foray, D. and J. Raffo (forthcoming), "An Analysis of Business-driven innovation through educational patents", in Vincent-Lancrin, S. (Ed.), *Business-driven innovation in the education sector,* OECD Publishing, Paris.

Figure 6.2. **Firms filing education-related patents, entry and technological concentration, 1990-2004**

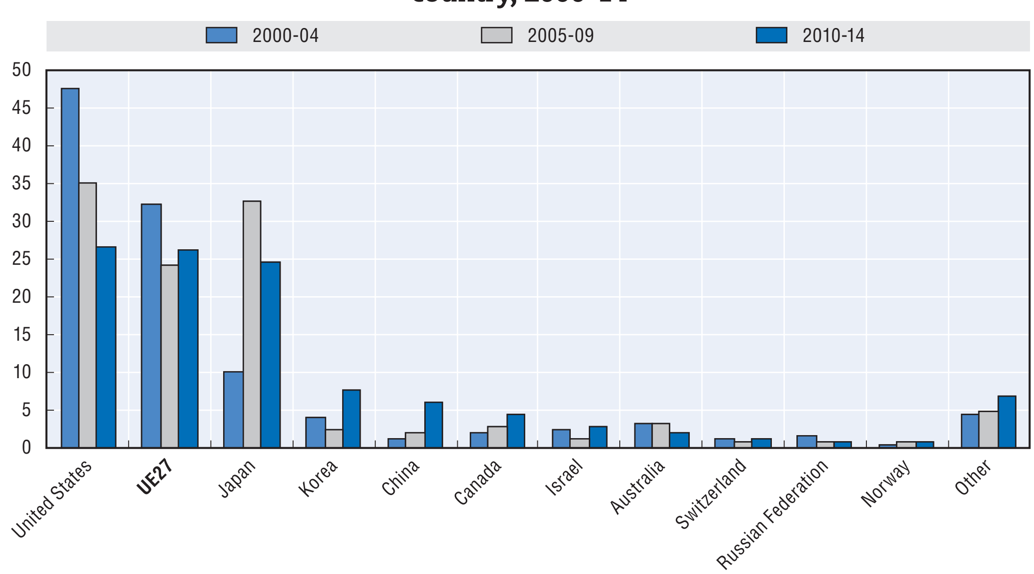


Source: Foray, D. and J. Raffo (2012), "Business-Driven Innovation: Is it Making a Difference in Education?: An Analysis of Educational Patents", OECD Education Working Papers, No. 84, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5k91dl7pc835-en*.

Foray and Raffo (2012) showed that until 2010 the top 100 firms filing patent applications in this category were major multimedia and/or electronics firms such as Panasonic. These firms manage their R&D by harnessing economies of scope, i.e. developing educational applications out of their generic technology, as part of a diverse project range. While the major non-specialist firms (those with fewer than 5% of their patents in that category) predominated in education-related patent applications, there is evidence that an innovation-intensive industry specialising in education is emerging: there has been a rise in the share of applications filed by specialist firms, owing particularly to patents filed by Chinese and Japanese firms. The list of the top 100 specialist firms (those with 50% of patents in the category) included smaller firms whose business model involves developing and marketing educational solutions. These specialist firms were mainly Japanese, Chinese and American.

The United States' share of education-related PCT filings has decreased significantly in the past 15 years, from 43% to 24%, and was more or less level with both the European Union and Japan in 2014. This fall is in line with what would be expected with the emergence of a specialised industry, and a decline in the filing of education-related patents by non-specialised companies. Japan's share of the world's education-related patents has more than doubled, and Canada, the People's Republic of China, and Korea have also recorded significant growth from a much lower starting point (Figure 6.3). Figure 6.4 shows this trend by country using a five-year moving average to smooth the growth. The growth in the European Union has been fuelled by an increase in education-related patent filings in France and the United Kingdom. Finland, Norway and Spain have increased both their number and their share of filings, while Germany, the United Kingdom and the Netherlands have lost some share. A similar sustained upward trend can also be observed in Korea, China and Canada.

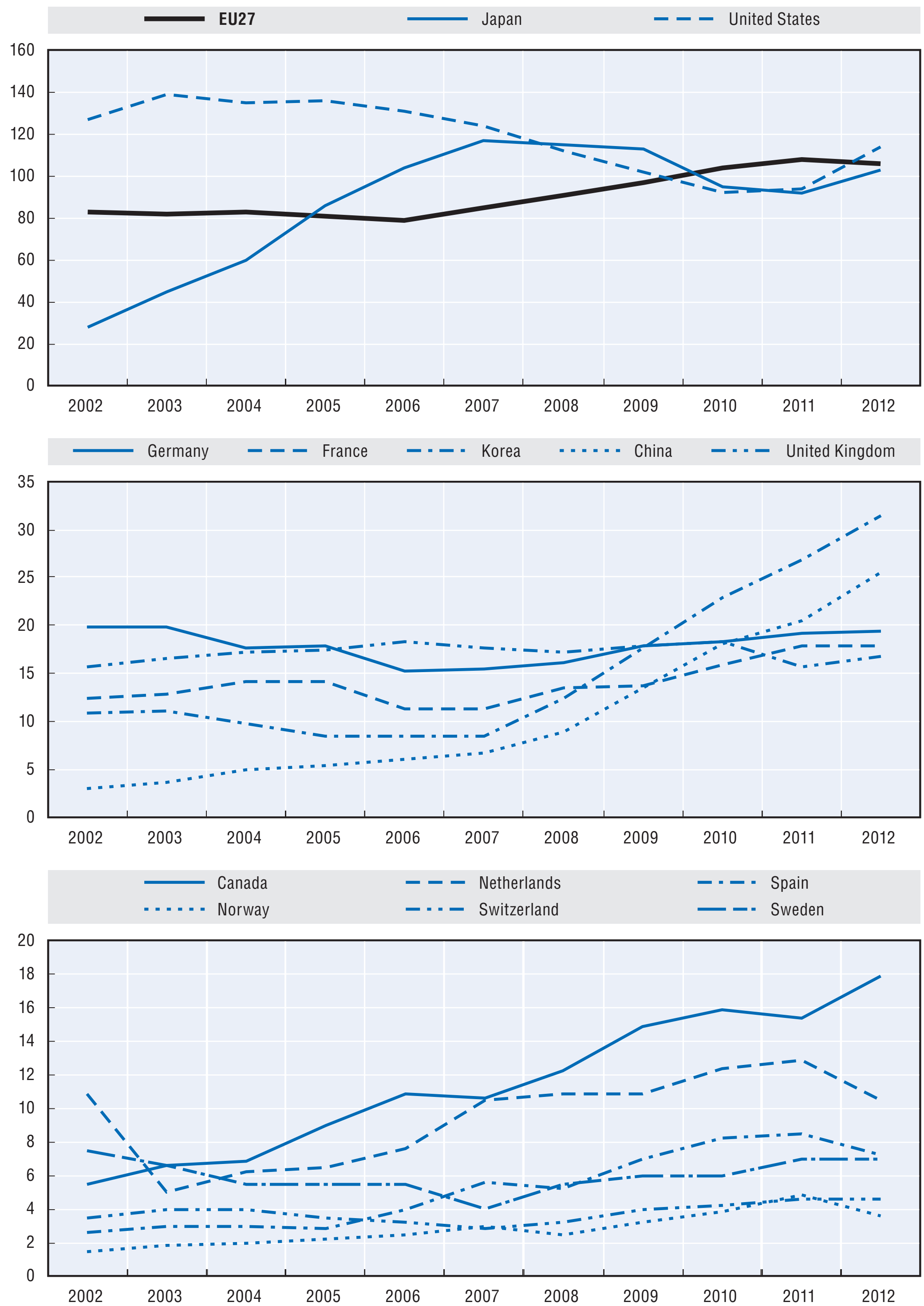
Figure 6.3. **World share of education-related patent filings by first applicant country, 2000-14**



Source: Foray, D. and J. Raffo (forthcoming), "An Analysis of Business-driven innovation through educational patents", in Vincent-Lancrin, S. (Ed.), *Business-driven innovation in the education sector,* OECD Publishing, Paris.

Figure 6.4. **Education-related patent filings by priority year and inventor's country, 2002-12**

Moving average (5 years)



Source: Foray, D. and J. Raffo (forthcoming), "An Analysis of Business-driven innovation through educational patents", in Vincent-Lancrin, S. (Ed.), *Business-driven innovation in the education sector,* OECD Publishing, Paris.

The development of instructional technologies in the wake of a great general purpose technology

Information and communications technology (ICT) is clearly a source of innovation in education systems: it offers a wide range of potential new tools and instruments to profoundly change the technological, organisational and institutional foundations of the sector. In education, the development of ICT provides opportunities to enlarge the repertoire of instructional technologies. The so-called process of co-invention of applications is not a minor matter since it is the process by which a new technology diffuses across a wide range of sectors and specific applications are generated.

In fact, the characteristics of a general purpose technology such as ICT lie in its horizontal propagation throughout the economy and the complementarity between invention and application development. In the economist's jargon, a general purpose technology extends the frontier of invention possibilities for the whole economy, while application development changes the production function of one particular sector. In other words, dynamic feedback loops arise as basic inventions give rise to the co-invention of applications in different sectors, which in their turn increase the size of the general technology market and the return on subsequent inventions. When things evolve favourably, a long-term dynamic develops, consisting of large scale investments in R&D with high levels of social and private marginal rates of return.

The growth in innovation exemplified by the rise in education-related patents seems to be strongly associated with the dynamics of ICT. The application of ICT in education should not be considered as a single innovation; it could result in an array of technologies that can be applied in a variety of ways. ICT can also be viewed as an enabler of change: schools engage in activities which they could not have done without it (e.g. Kärkkäinen and Vincent-Lancrin, 2013; Avvisati et al., 2013; European Schoolnet, 2013). It would be however premature to claim that the education sector has already reached the position of a central user sector with the potential to significantly boost the dynamics of ICT – or that ICT has significantly changed the technical core and way the sector operates.

Discussion

An emerging educational tool industry

In summary, the data show fairly intensive innovation activity around the development of new instructional tools and technologies. The locus of this activity is not really inside the traditional frontiers of the sector. A tool industry is being formed: a population of specialised firms that invent, design and commercialise educational tools. As in any historical example of a tool industry emerging, this involves a process of relocation of knowledge at least in part away from the point of delivery of the educational service. A shift in knowledge "holding" is taking place as a new site of knowledge accumulation emerges: the tool producer. Historically, one important reason for the emergence of a tool industry (beyond the classical reason of a growing market) is the rise of a systematic approach to the problem of increasing productivity. The process of relocation of specialised knowledge about tools away from the institution which delivers the final service – in this case the school – allows generic and multi-purpose machines and tools to be produced, replacing the specialised tools which would formerly have been developed within each organisation delivering the service.

Historically, the formation, emergence and development of tool industries have often generated efficiency gains and economic growth through greater specialisation, intra-segment competition between tool producers and an effective co-ordination between the tool companies and the downstream organisations.

Given the discussion above of the innovation deficit at the heart of the education system (the classroom), the emergence of a growing population of entrepreneurs in the market for new educational tools is good news. Companies competing to invent and commercialise tools can be expected to play a great role in enhancing innovation and productivity in the downstream sector.

However there is a need to qualify this optimism. One important concern is whether the public sector will be able to exploit the opportunities offered by the emerging tool industry. Another concern is the increasing activity of patenting. While small specialised firms need the legal monopoly granted by patents to enter and thrive in the market, they are likely to adversely affect efficiency in the short run (static efficiency) by putting a price on the kind of ideas and knowledge which used to be freely accessible.

Patent problems with the new structure

The development of a market for instructional tools may mean that potential users must now pay in the form of licensing agreements to access methods and knowledge that they used to obtain for free. In educational communities, some of the new patents are likely to generate great anxiety as practitioners realise that they are infringing patents and violating the law just by applying methods and practices that they have used freely all of their professional life. Researchers in biomedical sciences are quite good at simply "ignoring" (in the sense of failing to obey) the patents on research tools. The firms which have been granted these patents either anticipate bad appropriability of their knowledge by granting licences on a large scale or simply tolerating infractions, especially by academic researchers. These norms and practices on both sides effectively minimise the social inefficiencies potentially generated by excessive patenting in biomedical research (the so-called anti-commons problem: see Heller, 1998). It is not clear whether school managers and teachers are in a position to behave similarly, or what the response of the small specialised firms holding the patents would be.

For example, in 2006 Blackboard Inc. was granted a patent by the US Patents and Trademark Office "for technology used for Internet-based education support system and method" covering 44 different features that make up a learning management system. Frank Lowney, Director of the IT management system at the Georgia College and State University Library wrote: "Much of what Blackboard claims to have invented really came from and was freely given by the education community. Now the community is being punished through a gross lessening of competition in this market" (*Cox*, 2006). For an associate professor of Medical Education, the real question is: "What are they going to do next, try to patent word processing and charge you royalties if you are using it in a classroom? If obvious uses of technology to facilitate teaching based on standard software applications are allowed to be patented just because they are used to support education we are in real trouble" (Inside Higher Ed, 2006).

The problem with Blackboard Inc's patents and, we suspect, hundreds of patents for educational technologies, clearly involves the now common conflict between open source communities, which are proliferating in the educational world, and for-profit businesses attempting to enforce their claims on some (software) patents. But there is also a new problem here about patenting in an area where traditionally the norms of public good and free access were strongly dominant.

Another problem with the vertically unintegrated structure of the emerging industry lies in the ability of the small specialised companies to capture the benefits of their innovation. Transaction and bargaining costs on these markets pedagogical methods are likely to be very high and patents may not be the most effective means to capture the value of the innovation (depending partly on how the first problem is going to be solved). The problems of the firms considered here are rather similar to the situation described by Cockburn (2003) with regard to the tools companies in the biotechnology sector.

A tool industry for what market?

Innovation needs entrepreneurship or at least needs a varied distribution of firms of different sizes and ages, including a strong population of entrepreneurs at one end of the continuum. Baumol has written extensively and convincingly on the role and crucial position of the entrepreneur or young innovative firms as a mechanism for fuelling innovation and as an organisational form which is needed to complement large companies' modes of operation. However, the educational sector seems to have high barriers to entry making entrepreneurial activities in the sector less attractive: the reward structure of the sector does not favour the competitive entry of new firms and radical innovators willing to take risks and be creative in return for potential huge private returns on R&D and other innovation activities. Berger and Stevenson (2008) have identified some of those barriers:

- The lack of investment in innovation of the education sector.
- The existence, in many countries, of a so-called "Big Edu" – an oligopoly of a few very large suppliers of educational resources which solve the problem of highly atomised demand by building an enormous sales forces; entrepreneurs cannot afford to play this game.
- Slow sales cycles, as buyers have too many people "in charge" at different levels (state agencies, districts or local authorities, schools).
- The constraint of needing pilot programmes to test an innovative tool that makes it impossible for start ups to sell at a scale that is economically viable.
- The lack of a business culture for managing innovation in school systems: rather than buying new tools and systems, administrators usually choose to solve problems by using existing staff more intensively because this costs "nothing" (people are already paid for). Few school administrators have formal training in business decision making or in calculating returns on investment.
- The treatment of teacher time as a sunk cost which means people generally see no benefit to saving this time.
- The frequent recommendation by public authorities that administrators should not meet with entrepreneurs and vendors to avoid any unfair advantages, creating a "vendor wall" that prevents them being informed about new solutions.
- The limited size of potential returns, and the long time required to get any meaningful return, which in turn makes difficult to interest venture capitalists, the main source of funding for the most innovative start ups. Angel investors could be a substitute to a certain extent.
- The possibility of foundations and charities giving away for free the very things that entrepreneurs are trying to turn into a business. This is one unintended consequence of a strategy of building a commons, a well-known phenomenon in developing countries, which is seen as killing entrepreneurial spirit.

Beyond all the problems identified above, the education public sector is also a special market in the sense that "the consumers" do not necessarily want to buy a better product every year that a restless innovative activity needs to offer and commercialise.

Figure 6.5. **Number of top 50 companies with a specialised education patent portfolio in specific markets, 2010**

Source: Foray, D. and J. Raffo (2012), "Business-Driven Innovation: Is it Making a Difference in Education?: An Analysis of Educational Patents", OECD Education Working Papers, No. 84, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5k91dl7pc835-en.*

This raises a quite disturbing puzzle: there are some intensive innovation activities but the market seems rather difficult so what are these entrepreneurs really doing? The solution may be straightforward: these companies are probably targeting other markets than the formal primary and secondary education sector. Corporate training, education during leisure time and tertiary education are perhaps smaller markets but they seem far more "entrepreneur-friendly". In 2012, an in-depth analysis of the top 50 specialised companies in patenting educational tools allowed us to identify in which education markets they operate. Figure 6.5 shows the results of our web search: 35 out of the top 50 specialised firms operate in the tertiary education market, while only 20 operate in the school sector. Fewer companies commercialise their inventions in the formal primary and secondary education system than in the other market segments.

Conclusion

The good news for education is that an educational tool industry is emerging; that is to say a population of small firms specialised in inventing and commercialising (mainly ICT-based) instruction technologies. New sites of knowledge generation and accumulation have emerged: the tool producers.

However the main commercial target of these companies is not the huge public school system. This market probably does not satisfy the conditions for attracting and sustaining a strong entrepreneurial activity in the tool business. Other smaller markets seem to be attractive enough for entrepreneurs and this explains to a certain extent why we have observed the patent explosion and some increase in the number of firms specialised in the tool business.

The issue now for education decision makers is whether the public school system could better exploit the opportunities offered by the development of a tool industry. Can the public sector muster enough innovation friendliness in terms of management practices, governance and culture, as well as funding and resource allocation logic?

An important question for further research is whether the invention of tools for corporate education (or training) and other "smaller" markets" has spillover effects in the sense of building user capabilities (in a very broad sense) in the large formal primary and secondary education sector so that this sector can learn how to exploit the opportunities offered by the growing educational tool industry.

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ANNEX A

Report from the 2015 Global Education Industry Summit, held in Helsinki on 19-20 October 2015

The following text provides a report, drafted by the general rapporteur and the session facilitators, of the discussions that took place at the first Global Education Industry Summit in Helsinki on 19-20 October 2015.

Summary

Discussion in each of the sessions was helpful in identifying challenges that could be addressed through collaboration between all of the parties associated with education and some of the solutions. At times different points of view highlighted tensions. Such tensions appeared, for example, where innovation reduced dependence on traditional teachers, possibly in a situation where there is limited supply of teachers pointed towards the importance of careful consideration of context.

The argument in support of analysis of context was also seen to be critical when considering taking a successful practice in one location and adopting it in another. As suggested at the summit, practice is not changed by having technology. It is not like fire. You can be warmed by simply standing next to a fire. Simply providing technology or making people aware of an innovative practice is unlikely to change anything. Greater care in management of change, perhaps through adoption of design thinking might hold greater likelihood of impact and points again to the importance of supporting communities and networks of practice to take practice forward.

Another tension lay in the tendency to view groups as homogenous. Students are students, teachers are teachers, commercial companies are commercial companies and policy makers are policy makers. Just as there seems to be increasing recognition of the benefits of personalisation for students' learning, so we should look at how to engage each of these other groups and the constraints or freedom within which they work. Those with solutions to promote, sell or share may still be excellent listeners and have the judgement to apply their creative thinking and experience to the learning challenge with which they are faced. Alternatively, they may be solely focused on their pre-prepared solution and be a less supportive party with which to collaborate. In similar ways, finding where teachers are in terms of the normal distribution curve of innovative thinking may indicate how likely they are to adopt and succeed with new ways of working and point towards the type of personal development appropriate to their circumstances.

Solutions to each of these challenges probably lie firstly, in the development of each of us as life-long and life-wide learners and implementers. It's partly about what we know, what we are able to do, and how we apply our knowledge and skills to the challenges we meet. That reflection on our own work is important in modelling the skills and behaviours that many of us appear to wish to see in our students.

Secondly we should focus on collaboration and assist set up the circumstances in which those behaviours are adopted and amplified – in order to seek and implement workable and supported solutions. Taking steps to develop the conversation between industry, governments and education professionals is one step towards setting the circumstances in which collaborations can develop. Providing mechanisms for networking and development of communities of practice is another way in which collaboration might be assisted.

Thirdly, in a more structured and evidence based way, we might learn from the experience of other sectors and consider their adoption in education. To do so would not simply be a question of looking at outcomes, but also understanding the policies, skills, guiding values, behaviours, and practices. The Global Education Industry Summit is a potential location for learning from such practice given the participation by industry and other organisations.

Further suggestions for actions included:

- Recognising the importance and strength of learning from times off line as well as times on line.
- Providing the circumstances in which government, industry and education can effectively "speed-date" and match potential solutions with challenges to be addressed.
- Recognising and articulating what constitutes an effective market for education technology and supporting its development in countries where none exists.
- Addressing the relevance of learning to life and student's future success and not presuming relevance – associated with "unlearning" some of the practices we have developed.
- Development of a culture of appropriate risk taking and learning from failure rather than viewing failure as purely a fault.
- Creating a shared resource of vignettes demonstrating the practices that are successful through government-education-industry collaboration.
- Creating a shared resource gathering information on leading schools using technology particularly well and how they are managing their relationships with industry and government to achieve optimal results.
- Markets for skills, enterprise and small businesses can have positive societal impacts, providing opportunity and hope to sections of the community that might have been excluded from traditional success. Finding ways in which industry and entrepreneurs can share their expertise and approach may help spread their practice more widely.
- Call for actions from each country participating in the GEIS2015 to suggest a number of new ideas and act upon them.
- Ensure that the over-riding vision for education-industry collaboration is clear and that actions are initiated in support of that vision.
- Ensure that the creative energy and ideas of children and students are engaged and supported.

SESSION 1 – Redesigning learning environments to better support learning

Three challenges were set for discussants:

1. Schools need a physical and digital infrastructure through which improved teaching and learning products can be delivered. However, using technology does not automatically improve learning – it is not an innovation like fire, where one gets a benefit just by standing near it. Instead, technology is a catalyst that can empower deeper content, more active learning, more authentic assessment, and links between classrooms and the real world. These are innovations we know improve learning. How can we ensure that schools are given the optimum digital infrastructure?
2. The range of knowledge and skills students need for a global, knowledge-based, innovation-centred economy is greater than can be taught in even the best classrooms during the school day. In the world of adult employment, people do business anywhere anytime. Working is no longer localised in an office but distributed throughout the waking life of the adult. Schools need to adapt learning to similar modes of living. The biggest difference between an industrial educational system and a 21st century educational system is extending learning life-wide, using technology to make any place, anytime a rich opportunity for learning and enlisting the help of parents, community members, and informal educators as students' coaches, mentors, and tutors outside of school. Technology is a vehicle for accomplishing this vision, as it already has in business and in wellness. How can we help learning become life-wide?
3. The biggest problem in education is scale. While phones and social media have gone to scale, education innovation hasn't. We can find wonderful learning environments that accomplish every educational goal one can name – but the vast majority of these are not scalable to new settings that do not have all the unusual conditions for success these innovations require. The big challenge for business in education is designing and implementing scalable innovations that adapt to the strengths – and weaknesses – at each educational site. As we have seen in other sectors of society, technology can be a powerful means for scale. How can we develop innovations that are designed for adaptation not simply adoption?

Discussants reinforced these challenges, or added additional ones:

1. We need to bring innovative approaches into the standards' infrastructure. Can we develop new ways of measuring which validate innovative approaches and how is this best achieved?
2. We must move forward in the light of evidence and experience, at the same time as enhancing teacher capacity and motivation. So how can we support teachers so that they act at the heart of innovation?
3. We need to use technology to improve teacher capacity, not provide a substitute. How can we avoid corporations using their significant investment to replace professional teachers with low paid substitutes?
4. The differences between educational challenges across Europe remain vast. How can we build on a Europe-wide interest in improving learning outcomes to take learning solutions to scale?
5. There is wide-spread agreement that learning needs to become more personalised, and yet most of the innovations remain fixated with mass roll-out. How can we retain the focus, while going to scale, on the individual child?

6. We need to improve educational outcomes for migrant children. For instance, how can we shorten the time it takes for migrants to learn a new language.
7. We know that we want more entrepreneurial young people, and we know that they will need ICT skills and knowledge. But what skills and knowledge precisely will be of value to them?
8. The world beyond education is changing very rapidly. For instance, computers have fundamentally changed the nature of maths, and yet we still teach maths as if nothing has changed. How can we get education to start moving at the speed of the world beyond?
9. The skills required in the labour market are changing. How can the two sectors of education and employers work more effectively together to generate better outcomes for young people's employment prospects?
10. Informal learning plays a much greater role in young people's lives than ever before. Learning in the family is now of much greater importance. What sort of infrastructure would better support family learning?
11. Most innovation doesn't come from the top, it comes from the bottom. How can we ensure that the sparks if innovation light system wide conflagrations?
12. What stops teachers innovating is not lack of budget or lack of will. It is lack of time. How do we make more time for teachers to plan and implement better practices?
13. We must remember that education is more than the core subjects of science, maths and literacy. How do we ensure that local traditions, culture and values continue to play an important part in the education of young people?
14. Education should be about improving the quality of people's lives and to do so we must better understand what young people want to learn and why. How can we create systems that allow pupils to self-organise to achieve their chosen learning?
15. We need to put more effort into improving education in the Southern two thirds of the globe. How can we focus on solving problems in these regions quickly ensuring that change is for the better?
16. Schools in Denmark have been focussing on life-wide learning. How can we build on this experience to allow more private companies, sports clubs and other organisations to support and enhance the learning of pupils in schools?
17. We should view learning as taking place in a much wider set of environments than in school alone.
18. New Zealand has a sophisticated Integrated education service. But is such organisation the prerogative of small more affluent countries, or can this model be applied to developing countries with huge resource challenges?
19. National Governments with responsibility for education are under huge pressure to get education right. Education is probably the biggest single activity for which each government is responsible. How can we turn this focus on educational progress at the political level into a force for good?
20. There are innovations that have been developed, trialled and have proved to be successful. But how can we make education systems more open to the adapting of such innovations?

The discussion was concluded with the reflection that what had emerged was a comprehensive list of challenges to address. The list of challenges proved the importance of opening up this dialogue.

SESSION 2 – Mobilising technology to widen access and improve quality

Education systems face the challenge of widening access to high-quality opportunities to learn. In the 20th century education at scale and standardization have led to an extraordinary expansion of education systems. However, scale and standardisation have had their limitations have not brought opportunities to all.

- Can technology do more to widen and differentiate access for disadvantaged learners?
- How can technology be harnessed to personalise learning and to fine-tune educational opportunities to each learner's needs?
- Which policies can and should be developed to ensure that all learners benefit from the best possible opportunities to learn?

The opening presentation in this session reflected on the challenges of widening access and improving quality at the same time. New educational resources including open education resources have made significant impacts, as have new formal and informal education environments.

Digital technologies increase access to education and opportunities to learn, but technology is not a magic wand, we need to think about other factors including access to technology and connectivity; social attitudes to learning; legal issues associated with use; skills and competences of learners and teachers; business and financial models.

In some countries access to technology and connectivity is considered a public good. The goal for all countries must surely be universal access to all that you need as a teacher and a student. We should also reflect on the growing influence of non-market entities and their ability to provide access. Services and offerings such as Wikipedia, Khan Academy, freely available press articles; video material through Youtube provide additional opportunities. Some governments decide to provide resources, often framed as Open Educational Resources; for example, content repositories in Belgium or Norway, Core Curriculum aligned state content in the US, open book publishers in South Africa and France, policies for teacher resources in France and New Zealand and open digital textbooks in Poland.

Availability and access to content itself will not transform education, although it can be a foundation for a good education. We should transform ways in which educators and learners make use of content; where appropriate we should move static content and traditional resources like textbooks; and towards new, more engaging materials that encourage curiosity, exploration, engagement and learning.

Discussants discussed some of the challenges of "Mobilizing technology to widen access and improve quality" and suggested that a vision for ICTs in Education must precede the development of systems, criteria, networks, clusters and cooperation as a foundation for improving quality in education. The discussion could be divided in the following six themes:

1. *Open educational resources*

Open educational resources (OER) are growing in breadth and quality, as is their use in classrooms, networks, and school communities. It is important to understand that "open" does not necessarily or simply mean "free of charge" but may also mean free in terms of ownership and usage rights. The use and adoption of OER materials is increasingly a matter of policy in schools, especially in the many disciplines in which high quality educational content is more abundant than ever. The goal is that OER materials are free to copy, free to remix, culturally sensitive, and free from barriers to access, sharing, and educational use.

The goal is to give students the flexibility to make their learning as effective and efficient as possible. Appropriate mentorship, especially for primary and secondary school students is essential.

Partial solutions may lie in developing and sharing appropriate policies for open educational resources built on cooperation between industry and the ministries and public organisations. Systematic development of networks and clusters may encourage joint development of an open education resource market.

2. Open standards

Better, more accessible services are best delivered through a truly open process: open to those who use our public services, and open to suppliers, of all sizes, so that competition and innovation can deliver improved services. Transparency and access to data should be at the heart of government and public services, making it easier for publishers to release data in standardised, open formats.

3. Research and development

Evaluation, research and development in terms of prototyping new approaches to use of materials, are required to ensure that progress is encouraged and good practice developed.

4. Teacher education

Teacher education should include purposeful use of IT for teaching, to equip and support teachers in development of core skills in teaching with IT and to encourage engagement of institutions of higher education and industry partners in schools. Such work could help to provide states, districts, schools, and teacher education institutions the foundations upon which the integration of technology in their programs can be built.

5. Education Leaders

The rapid and continuing development of technology in schools requires a new generation of leaders who to use these new tools to enhance their own productivity and decision-making activities and who understand the benefits of integrating technology into learning. Such mature leadership in use of technology includes understanding of when it can provide real benefit, and it cannot. Leadership is often the most important factor in successful integration of ICTs into the school's instructional practices and curriculum. Research has shown that without effective and supportive leadership, changes in the teaching-learning process and widespread, effective uses of technology in learning are not likely to occur.

6. Personalized learning

A key opportunity for technology's use in support of learning lies in its potential to support and develop students' personalized learning. Software can track and indicate learners' progress in relation to learning objectives, reflect their state of knowledge granular levels, and use gathered evidence to suggest an appropriate next step for each student. Technology has the potential to learning plans more flexible and personalised, and to assist in making students' learning and teacher's teaching as effective as possible. Such personalization can assist not only within the school system, but also in life-wide and life-long learning.

SESSION 3 – Digital Revolution Supporting Pedagogies and Teachers

Digitisation challenges everyone, but also enables new opportunities. Teachers in particular have a role to play. However, is simply 'going digital' enough, or should digitization be considered an opportunity to rethink pedagogies and teaching practices, and more broadly, change working cultures in education?

If digitization is such an opportunity, then policy making should respond by providing new opportunities for teachers, so that students benefit from new opportunities to learn and to demonstrate their creativity. New pedagogies should meaningfully make the most of digital devices and resources.

Making such digital change in education cannot be left to schools and educational institutions alone; it requires smart innovation in devices, software, materials and, of course, associated development of teacher competences and strategies and school communities as a whole.

In most countries governments are not at the steering wheel of digitization, but they can certainly set the framework conditions. We need innovators and experts from government, business, research and education to work together to develop and implement new approaches for educating and supporting teachers so that they are well prepared and equipped to face the digitisation challenges. How can and should governments and industry work together to support this?

The digital revolution is a very real revolution. The opening presentation of the session highlighted two of the fundamental shifts in learning and education that are having an impact on pedagogies and teaching practices:

- Increasing access to information and educational material
- New ways of presenting the material, reflecting on it and discussing it

In terms of access to information, digitisation is introducing many new and more possibilities than ever before. Traditionally, students were limited to access to a textbook and to a teacher. When trying to solve a problem in class, students could study the textbook or ask the teacher. Now things are different – connectivity, devices and access to a world of information in digital format is fundamentally changing this dynamic.

In terms of presentation of learning material and how discussions in class and beyond take place, digitization has introduced many technological developments, discussion on the digital revolution to concentrate has tended to concentrate around presentation, rather than access to information. In the longer term, the revolution in access to information is likely to have a greater impact than the changes in the presentation.

It seems obvious that digitization should be considered an opportunity to rethink pedagogies and teaching practices, and more broadly, to change working cultures in education. The real questions are, however, how will this change happen and what is the role of policy makers?

How do we provide new opportunities for teachers to make new and make the most of new pedagogies? We need innovators and experts from government, business, research and education to work together to develop and implement new approaches for educating and supporting teachers so that they are well prepared and equipped to face the digitization challenges.

Building innovative capacity into education: pedagogies and teaching

Building innovative capacity into education: pedagogies and teaching is therefore a conversation about change and one of the words you rarely hear in the context of change is 'easy'. We also know that 'being right is not a strategy for change'[1] – today's pedagogies and teaching practices may be very effective in the here and now, but need to be reviewed constantly to take account of the challenges of the future.

So the fundamental issue is how to build innovative capacity into the education system. Innovation and education are in many ways unhappy bedfellows. We desire the ability to take risks but we want to avoid risk-taking. We desire innovation but we want stability. We also have to be wary of our desire in education to depend entirely on 'evidence-based change' – the time taken to generate research evidence to support innovation in a rapidly evolving technology cycle presents a fundamental paradox. Maybe the answer lies in better and faster sharing of research evidence using non-traditional means.

We need a vision supported by the courage to change – for example, in fundamental areas such as how we teach subjects. Identifying a vision of where we are trying to get to – as opposed to the mechanics of how to get there – is perhaps the most challenging aspect in the context of policy making.

The fundamental question for education systems is now how to remain relevant in a world of educational alternatives. The discussion within the session was wide-ranging but can be distilled into four key themes for building innovative capacity:

1. Teacher education - rethinking CPD

To support teachers, we should build the capacity to change and to innovate into teacher education. We need to strengthen the capacity of teachers to make use of latest findings and empower them to deploy that in the classroom. If we are asking teachers constantly to do better things (Cf. simply doing things better) then we need to think about how to best help teachers. Part of that is about 'unlearning', which requires affective and social support.

One of the answers may be with an innovative learning system to support teacher development. Taking cues from the corporate learning world, the issue is one of performance support rather than 'training'. An innovative support system for teachers could include 'learning at the point of need – rethinking the paradigm for CPD.

Importantly, bottom-up change also requires teacher-led collaboration. Trends such as content sharing, content curation and online collaboration building trust are essential to develop an innovative ecosystem.

2. Design thinking – supporting innovation

Introducing design thinking into the process of innovation around pedagogy and teaching practice could also deliver results. Take a cue from world class digital designers – designing for use with digital is a different discipline requiring, for example, an understanding of issues such as UI/UX (User Interface/User Experience understanding). There may also be an opportunity to develop simple 'rules of thumb' such as: only use technology to do things better.

3. Models of assessment

Digital pedagogies and new teaching practices imply new models of assessment. There is a widespread recognition that you can't assess knowledge in the same way that you teach it, but how do we improve assessment literacy to support innovation? How to move away from a situation where we continue to value what we measure, rather than measuring what we value. Undoubtedly, as students generate massive amounts of valuable data through digital interactions, learner analytics, personalization and adaptive learning take on a whole new importance.

4. Student voice

We can learn a lot from how students engage with new technologies and pedagogies. In the digital gaming industry, there is a philosophy of 'Player First', giving players an embedded role in product development – maybe a 'Student First' approach to developing pedagogies could also be adopted. There are many examples of ground-up movements driven by students – for example Coder Dojo and Digital Youth Councils.

SESSION 4 – Partnerships for transformative education policies

"How to create transformative education policies?", that was the question. "Through partnerships" was the answer.

There was a very strong consensus among the participants that forward-looking education policies require a very close co-operation between industry, schools and authorities. That is the starting point. However, it is not enough. We also need:

- Networks of like-minded people
- Clusters where start-ups and teachers; researchers and educators; parents and business leaders; artists and students can experiment with new ways of learning and new ways of teaching
- Leadership from policy-makers.

It was noted that we are entering an unprecedented era of learning. It is an era of new opportunities but it is also an era of a great disruption. Future class rooms and schools may look very different from what we are used to seeing. Methods of teaching may seem strange compared to those of the past. One thing is, however, likely to remain: learning takes place in a fruitful interaction between a teacher and a student in a structured environment. The task at hand is to create as fruitful an environment for learning as possible.

The session started with a discussion about the uncertainty created by technological change and by government cuts in many countries. It was felt that sometimes there is "change for change's sake". Better coordination was called for.

A central theme in the discussion was whether a well-functioning educational market already exits. It was felt that in a few countries such a market does indeed exist. In addition to book publishers, authors and illustrators it includes technology companies, software developers and other players. In other countries, there is no educational market. Partnerships can be a step toward creating a proper educational market where public and private actors can find each other. It was pointed out that governments must avoid policies or creating institutions that crowd out market-based solutions.

Participants emphasized that collaboration between education industry, ministries and schools must be concrete and open. It must be based on clear standards and platforms. And it must be open to everyone to participate.

Collaboration between vocational schools and industry must be as pragmatic as possible. It must provide new and authentic skills and work experience.

Partnerships can be developed through experimentation. "Speed-dating" between educators and start-ups was mentioned. "Experience visits" to companies or research centres was another example. Getting parents involved in different aspects of education was also deemed valuable.

The role of technology was discussed in length. It was pointed out that technology amplifies both good and bad teaching. We must not lose sight of the fact that quality teaching is and will remain in the centre of the learning process.

Discussants also noted that:

1. We need advancements in technology to create connectivity and access across the globe.
2. We need powerful and less expensive devices, interoperability standards, APIs, single sign-ons, platforms and more. These are technical and engineering solutions
3. We need researchers - neuroscientists and cognitive scientists and other fields of study to improve our understanding to how people learn.
4. We need support for research and development, product testing methods and protocols, learning analytics and data mining.
5. We need entrepreneurs and designers and start-ups to create and pursue solutions to challenges both grand and small.
6. We need teachers and teacher teams to provide deep insights into pedagogy, the best ways to manage groups of students, the methods for engagement and motivation, ways to engage students with relevant and powerful problem solving. Teachers design curriculum, new assignments and share insights into evolving pedagogy.
7. We need governments and policy makers to ensure laws, regulations and policies that keep our sights on the public good, ensure safety and security, and promote rather than hinder innovation.

Together we are capable of developing powerful, purposeful networks that connect the right people, and organisations. If we can develop these partnerships, we will offer the world something of value.

Notes

1. This quote belongs to Michael Fullan, who used it in his keynote to the CoSN Conference Atlanta, March 2015.

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Education Innovation and Research

Innovating Education and Educating for Innovation

THE POWER OF DIGITAL TECHNOLOGIES AND SKILLS

OECD's Innovation Strategy calls upon all sectors in the economy and society to innovate in order to foster productivity, growth and well-being. Education systems are critically important for innovation through the development of skills that nurture new ideas and technologies. However, whereas digital technologies are profoundly changing the way we work, communicate and enjoy ourselves, the world of education and learning is not yet going through the same technology-driven innovation process as other sectors.

This report served as the background report to the second Global Education Industry Summit which was held on 26-27 September 2016. It discusses the available evidence on innovation in education, the impact of digital technologies on teaching and learning, the role of digital skills and the role of educational industries in the process of innovation. The report argues for smarter policies, involving all stakeholders, for innovation in education.

Contents

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