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Abstract

Education should play an important role in improving European Union (EU) status in the context of stagnated GDP growth, very high unemployment rates, and an aging workforce. Although educational technology is expected to contribute to improving education in the EU, compelling evidence of the benefits of technology on education remains elusive.

In the current Network Society, the relevant question is not if governments should invest in educational technology but how governments should allocate funding in order to add more value to the educational system through technology.

Educational technology encompasses a wide array of technologies and methodologies that are shaped by stakeholders' behaviours and affected by contextual factors that, if adequately mixed, can contribute to students and teachers better achieving their goals.

Such a wide and complex task cannot be addressed by a simple and single intervention. Comprehensive on-going policies are required, covering technology, methodology, economic and regulatory aspects; in addition, such policies are dependent on strong stakeholder engagement. This is a new process where we must learn by doing; therefore, carefully assessing the results of the different interventions is crucial to ensuring success.

The following topics are analysed in this report: emerging educational technologies, new ways of teaching and learning fostered by those technologies, the role of different educational stakeholders, and other contextual considerations. Based on the analysis, and taking into account the challenges facing Europe, several policy options are proposed and assessed. We expect that this report will support EU policy-makers to define educational technology policies to adequately respond to the needs of the EU.

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LIST OF ABBREVIATIONS

BRICS	Five major emerging national economies: Brazil, Russia, India, China, and South Africa
BYOD	Bring Your Own Device
CCK08	Connectivism and Connected Knowledge Course
CCR	Creative Classroom
CV	Curriculum vitae
EC	European Commission
FMRI	Functional magnetic resonance imaging
GDP	Gross domestic product
HSDPA	High speed downlink packet access
ICT	Information and communication technologies
ILS	Integrated learning systems
IP	Internet protocol
IWB	Interactive whiteboards
LLL	Lifelong learning
LMS	Learning management systems
LTE	Long-term evolution
MB	Megabyte
Mbps	Megabits per second
MIT	Massachusetts Institute of Technology
MOOC	Massive Open Online Course
MSL	Mobile seamless learning
NGO	Non for profit organization
NUI	Natural user interface
OCW	Open course ware
OECD	Organisation for Economic Co-operation and Development
OER	Open Educational Resources
OLPC	One Laptop per Child
OSs	Operating systems
PET	Positron electron tomography
PISA	Programme for International Student Assessment
PPP	Public private partnerships
R&D	Research & development
RoI	Return on investment
SME	Small and medium enterprise
SNS	Social networking sites
STEM	Science, technology, engineering and mathematics
UE	European Union
UK	United Kingdom
UMTS	Universal mobile telecommunications system
UNESCO	United Nations Organization for Education, Science and Culture
US/ USA	United States of America
VoI	Value of investment

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EXECUTIVE SUMMARY

Throughout human history, disruptive technologies such as the birth of writing or the appearance of printed works, were considered to revolutionize education. Nowadays, once again, the irruption of digital technologies and the Internet are expected to substantially change the educational system. However, compelling evidence of the benefits of technology on education remains elusive. Progress is undeniably being made although at a much slower pace than anticipated.

Educational technology is not a single and simple intervention; rather, it encompasses a wide array of equipment, tools, services and practices that can help students and teachers throughout the educational process to better achieve their goals. Technology by itself does not result in better education; rather improved results are achieved by the manner in which technology is effectively integrated into the educational process.

This report intends to provide helpful insights about these complex and challenging topics by analysing the following: (1) new and emerging educational technologies; (2) new ways of teaching and learning fostered by those technologies; (3) the role of different educational stakeholders; (4) the future of education in the European Union (EU); and (5) other considerations. Based on the aforementioned analysis, several policy options are proposed and assessed.

New and emerging learning technologies

Technologies influencing education have been grouped into: enabling technologies, cloud technologies, devices, technical support as well as educational contents, tools and services.

The majority of schools in the EU have broadband connectivity; access to the Internet has substantially improved over the last years. However, a lack of ultra broadband connectivity at the school level — with speeds higher than 100 Mbps— can seriously hinder the adoption of new teaching and learning practices that require high bandwidth. At the household level, there are high penetration rates of broadband Internet access, although with persistent disparities depending on the socio-economic status of households.

Digital contents, applications, and services are increasingly being delivered on demand through the Internet from shared infrastructures managed by third parties through the cloud computing model. This model has several benefits in the educational environment, such as the fast provision of new services, easy infrastructure scaling, reducing the required initial investment in an environment of budget costs, and allowing public managers to draw upon complex innovations without the need to implement unfeasible changes in their organizations. These are the reasons the market of cloud computing in education is expected to more than double over the next 5 years.

The connected society has shifted from fixed connectivity based on shared personal computers towards a mobile multimedia personal connectivity characterized by fast and persistent connection and ubiquitous access. The Internet is becoming mobile. Between 2013 and 2018, mobile data traffic is expected to grow 3 times faster than fixed traffic. From an educational perspective, mobile networks provide greater flexibility to deploy new ways of teaching and learning, and to overcome physical and time barriers when accessing education. Smartphones are the main beneficiaries in the context of this shift. The market share of smartphones will continue to grow, accounting for 74.1 per cent of the total connected devices in 2018. Surprisingly, in this environment of personal mobile devices, the majority of teachers and students access digital resources through a shared fixed computer. It is expected that in the medium-term, personal mobile devices, such as wearable devices, tablets and smartphones will play a much more relevant role in the educational environment.

The Internet has substantially changed the contents industry by decreasing the production costs, promoting collaborative creation, and by creating global markets where contents can be easily provided worldwide. As a result, digital contents are becoming the most relevant source of traffic on the Internet. There is also an increasing trend towards making educational contents and resources freely available through what it is called the Open Educational Resources (OER) movement.

Other services and tools that might have a substantial impact on education are mobile apps, social media and artificial intelligence systems. Mobile apps are expected to be an increasingly relevant media with which to deliver educational contents and services. Currently, educational apps are the second largest category in the Apple store and the sixth largest category in the Google Play store. Social media, when used in the educational context, allows teachers and students to communicate and access content anytime, anywhere, particularly when accessed in mobility. Their use, in addition to providing ubiquity and flexibility to the educational process, enhance collaboration, participation and creativity thanks to co-creation of contents and knowledge. They are also a new source of information that can lead to creating personalised environments adapted to the specificities of the students. Finally, virtual assistants might have vast application in higher education and lifelong learning and can boost self-driven learning.

New ways of teaching and learning

Deploying technology at schools alone will not transform education. Technology should be considered as an enabler for innovation. Its integration into the educational process needs to simultaneously take place with innovation in the curriculum, pedagogies, and the organization to improve learning outcomes and achieve the goal of providing the right skills to increase competitiveness and employability.

One crucial element of this holistic innovation approach is the curricula. Curricula at K-12 levels have remained largely unchanged for decades. There is a general consensus that they need to be revamped. Some authors argue that the curricula should be reformed in a manner which stimulates further creativity and innovation, while others claim a total review of its content and structure is required. Together with the reform of the curricula, a review of the assessment procedures is required. If the required skills are shifting, the way in which they are assessed should be modified to accurately judge if the objectives have been achieved.

Learning and teaching practices constitute the third element necessary to truly innovate and ensure the effective integration of technologies in education. The learning environment has to be transformed into a “Creative Classroom,” an innovative learning environment where teachers adopt the role of facilitators or coaches, and the experience of learning for students is flexible, personalised and fun. The report includes a brief review of the most relevant trends regarding learning and teaching practices aimed at transforming the classroom: mLearning, 1to1, Bring Your Own Device (BYOD), self-driven learning, personalised learning and assessment, peer to peer assessment, flipped learning, game-based learning and gamification, collaborative learning and collaborative creation, Massive Open Online Courses (MOOCs), seamless learning, and learning analytics.

The role of the stakeholders

School leaders are important catalysts for change; they play a crucial role in fostering an environment where technology is smoothly integrated into the educational process by providing strategic vision, defining consistent priorities, establishing clear goals, creating a supportive environment, and developing actions aimed at transforming closed institutions into connected open learning communities.

Teachers’ skills, attitudes, abilities and experience are the most relevant factors affecting the way technology is used in the classroom. Teachers need to be properly trained not only in technology, but also in methodologies and abilities to integrate technology into the educational process. Lack of teachers’ confidence in their technology skills in the EU yields teachers using technology only to prepare their classes without fostering new ways of learning and teaching.

The role of students is becoming increasingly active in the new digital environment. Students are expected to develop and share information and contents, give their opinions, interact with other students and teachers, and even assess the results of their mates. However, inadequate digital competences of the students are hindering the process. Although students are considered digital natives, only 30 per cent of EU students can be considered digitally competent.

Families are responsible for providing a home environment that supports digital learning. It leads to strong inequalities because family income and parental education are strongly related to digital and achievement gaps; this relationship is expected to grow in the absence of further effective measures.

In cooperating with schools, governments, and companies, non-profit organizations (NGOs) can bring different stakeholders together to share knowledge, provide equipment, train teachers, families, and students, as well as raise awareness.

The industry is the main provider of technology infrastructure, contents, and applications. However, the EU is missing the opportunity to lead the development of valued added e-learning products and services, while the US and certain Asian countries are increasingly becoming leaders in this area.

The future of education in the EU

The EU is facing a challenging situation with stagnated GDP growth and very high unemployment rates. The ageing population in the EU compounds the problem by forcing retraining workers in a fast evolving environment to keep the productivity level. With regards to education indicators, the EU is not performing significantly better in comparison to China or Korea. Although EU countries are achieving average results on PISA scores (which have improved slightly over the last 3 years), certain Asian countries are performing better and improving faster in comparison to the EU. Strong disparities also arise in education performance among EU countries.

There is a strong relationship between education performance and macro-economic indicators, and this relationship seems to be more intense within the EU, particularly for unemployment rates. It suggests that the EU economy is more dependent on having a highly skilled labour force due to a larger number of technology-based industries. Although having a highly skilled population is crucial to maintaining competitiveness, the EU has a high percentage of youth with low skills to solve problems in technology rich environments and the situation is not improving.

Educational technology can contribute to improving the educational achievements and skills of youth, and maintaining the productivity level of an ageing workforce, thus increasing the competitiveness of EU workers in a global and fast evolving economic environment.

With regards to technology at the school level, the analysis shows that the countries with the highest academic achievements tend to use computers in education moderately. In fact higher levels of computer use seem to be related to a higher percentage of students performing poorly. These results demonstrate that the manner in which computers are used is more important that the numbers of computers a school possesses.

Technology is also supposed to facilitate lifelong learning by promoting ubiquitous access to quality educational contents. Consequently, it is expected that education through technology may play a pivotal role in reducing high unemployment rates in the EU and providing new skills to older workers. However, the analysis suggests that less educated and older populations are highly unlikely to be involved in lifelong education activities and this is particularly true for new ways of education (open and distance education) fostered by technology.

Other considerations

Return on investment

In the current environment of budget cuts and increasing social pressure towards public sector efficiency, performing careful evaluations of the costs and benefits associated with investments in educational technology has become increasingly important. The most frequently used methodology to evaluate public investment is cost-benefit analysis.

The short-term benefits of technology in education are related to improved academic achievements, while the long-term impacts affect individuals and the society as a whole: increased productivity and employability, higher earnings, and other intangible benefits of having a better educated population. Assessing those benefits is a challenging task. Most of the benefits are difficult to capture and quantify, particularly in the long-term, and it is difficult to isolate the true causes (and therefore the costs) behind those benefits.

The second digital divide

The digital divide between affluent and poor families in the EU is more than 40 points. At the school level, although the situation has improved over the last years, between 18-28 per cent of students depending on the grade, lack access to Information and Communication Technologies (ICT) both at home and at school. Moreover, the divide is not only about infrastructures; rather, it is also about how technology is used. Once the infrastructure is available, the inequality emerges as a result of an inability to properly use the technology - the so-called second digital divide. Digital inequalities in developed countries are arising as a side effect of the large-scale implementation of technology in schools. This knowledge gap can affect people's income, their social mobility and ultimately their quality of life more than the achievement gap; it can also result in productivity loss and affect ICT growth. Conversely, there is a valuable side effect in solving the educational digital divide: it can fast track the process towards a more efficient and fully digitalised society.

Regulations and ethical issues

The use of technologies in education encounters various regulatory and ethical issues. We have identified four main areas with legal and ethical implications that should be taken into account when deciding upon policy options: cyber security and privacy, intellectual property rights, standardisation and interoperability, and the recognition of informal education and new skills.

The increasing use of emerging technologies in education and within schools raises concerns about privacy and security issues. The use of cloud-based technologies in schools might result in risks regarding the protection of students' private data, such as: the ownership of the data, the regulatory compliance depending on the location of the data, the technical and administrative protection measures, and the transparency of agreements regarding the disclosure and uses of students' information. Learning analytics raise three main types of ethical concerns: location and interpretation of data, informed consent, privacy, de-identification of data, and classification and management of data. Data protection policies and regulation should seek a balance between the protection of fundamental rights and promoting innovation by effectively protecting citizens while minimising their potential negative impact on the development of learning analytics products and services. Eventually, the increasing use of Internet augments risks such as cyberbullying or grooming.

One of the most relevant barriers to the development of digital educational resources in the EU is the lack of a clear and harmonized legal framework. The current European intellectual property regime hinders the creation and use of online educational contents, and generates uncertainty for educators and learners.

A lack of interoperability between operating systems and platforms, and a lack of portability of resources may hinder the full exploitation of the benefits of educational technologies. If applications and contents do not run seamlessly through devices, technology options are constrained and costs are increased. The mobile ecosystem is dominated by two operating systems: Google's Android and Apple's iOS, together accounting together for over 90 per cent of the market in the EU. These companies set their own closed standards resulting in difficult interoperability for commercial reasons. This market dominance restricts business opportunities for EU service providers and developers, thus hindering innovative learning practices.

Evaluation

Regarding technology in education, it is particularly important to continuously design and implement new policies as well as assess the results of these policies. Evaluating policies can be particularly interesting in the EU where results of different policies deployed at the national and regional levels can be easily compared; this creates a natural policy lab that could substantially improve the effects of the policies in the medium-term. Evaluation should not be focused on technology itself but on how technology is integrated into the educational process following a comprehensive approach. Moreover, the effects of educational policies should consider a wide variety of short-term performance indicators and long-term achievements.

Policy options

The main challenges identified in the analysis are as follows: (1) a lack of compelling evidence pertaining to the benefits of the different technology options in education performance; (2) persistent inequalities both among and within EU countries; (3) increasing speed of the technological evolution; (4) a lack of strong involvement of relevant stakeholders: teachers, civil society and the industry; (5) an inadequate regulatory framework; and (6) budget pressure.

There are several options available to policy makers that can contribute to addressing the educational technology challenges facing the EU. An assessment matrix is used to assess how adequately the different policy options address these challenges. The assessment criteria used in the analysis include: (1) managing uncertainty, (2) tackling inequality, (3) innovative approach, (4) stakeholder engagement, (5) regulatory concerns, (6) budgetary feasibility, (7) political feasibility and (8) feasibility in the EU context. Based on the analysis, and taking into account further political and socio-economic considerations, policy makers may select the policies, which best reflect the interests of EU society.

The policies are classified into four groups: technology policies, stakeholder's engagement policies, competitiveness policies and cross-cutting policies.

Technology policies

- Extensive deployments of technology at the school level
- Pilot based deployment
- Defining and reaching a minimum threshold of infrastructure at school
- Sharing infrastructure and services in the cloud
- Drawing upon students' devices
- Drawing upon open and collaborative environments to create educational resources

Stakeholders' engagement policies

Teachers

- Reforming educators' training and assessment systems
- Implementing specific Continuing Professional Development (CPD) plans
- Promoting collaborative transnational educators' communities

Industry

- Promoting public-private partnerships
- Involving the industry in the policy-making process to better align its needs with that of the education sector
- Strengthening cooperation in innovation and research
- Boosting innovation in the industry of contents and services

Families

- Carrying out awareness raising campaigns
- Implementing economic incentives

- Direct provisioning of technology and training services

Competitiveness policies

- Adapting the curriculum
- Designing and officially recognizing new assessment methods
- Shaping the role of MOOCs to effectively contribute to lifelong learning
- Increasing the recognition of informal education

Cross-cutting policies

- Creating tools to properly evaluate policies

1. INTRODUCTION

Technology seems to be the next big revolution in education. Schools will no longer be the same, books will likely disappear in classrooms, the barriers between teachers and students will be blurred, high quality contents developed collaboratively will be available for free, and tailored education for all will be accessible anytime, anywhere through mobile personal devices, thus promoting lifelong learning. However, things are not proceeding as expected. Considerable public investments in educational technology have not achieved as many results as expected and compelling evidence of the benefits of technology on education remains elusive (Livingstone, 2012). Progress is undeniably being made, however, at a much slower pace than anticipated.

Educational technology is not a single and simple intervention than can improve education; rather, it encompasses a wide array of technologies, tools, services, and methodologies that can help students and teachers throughout the educational process to better achieve their goals (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011, p. 19). It is not technology itself that matters the most; rather, it is how teachers, students, families, and school leaders use the technology. Creating pervasive technology environments in the educational system without having clear goals can do more harm than good. Providing computers to students in low-income families may substantially worsen their educational outcomes (Vigdor & Ladd, 2010). Education is a complex system and technology by itself may have unintended consequences if not properly used. The goal is to create a positive and innovative environment where technology could be successfully integrated into the educational process. The effect of new and emerging learning technologies on education is a complex topic with several intertwined factors affecting each other: how technology and the foundations of the learning process are related to each other, which are the main technology trends, what emerging learning and teaching methodologies are fostered by these technology trends, and how stakeholders are shaping and applying these technologies and methodologies in the different educational levels. Moreover, other relevant topics also play an important role, such as whether or not these technologies will foster further inequalities and the role of researchers and the industry—providers and consumers of education at the same time—in this new environment.

The persistent economic meltdown and the challenges facing the European society in the globalized and digitalized environment has lead Europe to a crossroad. How can Europe increase competitiveness and productivity to reduce unemployment and increase wealth? What is the role of education, and particularly technology in education, in this process? What can policy makers do to draw upon the potential benefits of using emerging technologies in education while avoiding their downsides?

This report intends to provide helpful insights about these complex and challenging questions. By analysing the former topics, and considering the current status of education in Europe, this study will present policy options to help policymakers develop appropriate policies in order to benefit from educational technology.

The document is structured as follows:

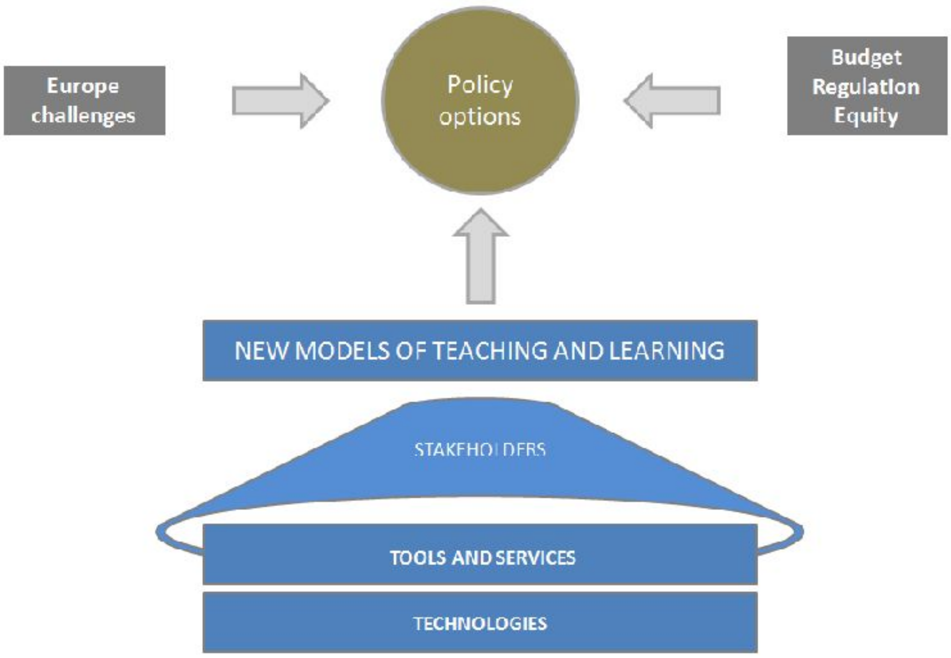
- Chapter 2: New and Emerging Learning Technologies, analyses the current status and expected evolution of technologies, and the tools and services that are arising as a result of these technology trends. Technologies are grouped into four main categories: enabling technologies, cloud technologies, devices and technical support. These technologies allow the provision of innovative educational tools, contents, and services, such as open educational resources, educational apps, advanced learning management systems, online collaboration platforms, data analytics and virtual assistants.
- Chapter 3: New Ways of Teaching and Learning, analyses innovative educational models arising in this environment. BYOD and 1to1 models foster the creation of ubiquitous pervasive technology environments. Data analytics promotes flexible and personalized

teaching and learning. Boundaries between teachers and students are being blurred by flipped learning, collaborative creation of tools and contents and peer-to-peer assessment. Personal devices and mobile networks foster "anytime anywhere" communication using ubiquitous social media. Further, virtual assistants support self-learning. MOOCS represent a promising trend to promote lifelong self-learning by combining flexibility, peer-to-peer assessment, collaboration and virtual assistants.

- Chapter 4: The Role of Stakeholders describes how the different stakeholders in the educational system, namely policy-makers, educational leaders, teachers, students, families, community and businesses shape the use of these technologies and tools depending on their interests, skills, and attitudes.
- Chapter 5: THE FUTURE OF EDUCATION , analyses the current status of education in Europe compared to other countries, particularly regarding the use of technology in education. Based on this analysis, the trends and future consequences for Europe are assessed.
- Chapter 6: OTHER CONSIDERATIONS, covers additional topics such as the economic impact of technology in education, whether educational technology can foster inequalities, regulation that could have an impact on speeding up the process and improving the benefits of educational technology while mitigating the problems, and the importance of carefully evaluating educational technology policies.
- Finally, Chapter 7: POLICY OPTIONS, analyses of the main alternatives available to policy makers.

Figure 1 shows the relationship among these topics.

Figure 1: General framework[1]



Source: Compiled by the authors

[1] Equity is defined as "the quality of being impartial or reasonable" and is related to the fairness of a policy, a programme or an action. The term should not be confused with equality that refers to the condition of being equal, that is, the same or alike. In some circumstances, policies that intend to increase equity need to treat people or groups with inequality, that is, in a different way, for example, by applying positive discrimination. Treating everybody the same is not necessarily fair and might result in inequities.

2. NEW AND EMERGING LEARNING TECHNOLOGIES

2.1. Foundations: How ICT impact our cognitive development

Nowadays, technology is no longer a mere tool; it underlines most of the activities of our life: the way we work, the way we communicate with others, the way we spend our leisure time, etc. The intensive use of ICT has an impact on human beings, both physically and mentally. Knowledge about the effects of these technologies, particularly in children, constitutes a valuable basis for understanding the potential role of ICT in the educational process.

The human brain is extremely complex and dynamic and it changes according to the way we use it. Changes in the neural pathways and synapses of the brain, called neuroplasticity, occur due to experiences and changes in our environment or context (stimuli and the brain's own activity). Neuroplasticity takes place during the development of the brain, when it begins to process information, and during the learning and memorizing processes. It also occurs when the brain adapts to situations such as brain injuries. Although brain plasticity is a lifelong phenomenon, there are certain periods of life, such as infancy and adolescence, when the brain is more susceptible to these changes.

For that reason, when studying the implementation and use of ICT in education, it is important to understand how these technologies affect our cognitive development. This understanding can lead to the reduction of risks and the development of better services and products and, in particular, more effective learning and teaching practices.

Neuroscience methods, such as functional magnetic resonance imaging (FMRI) or positron electron tomography (PET), allows one to observe the brain during the learning process and identify which circumstances or conditions affect this process. In particular, neurodidactics study how learning and memory can be influenced (Sabitzer, 2011). Thanks to the cited disciplines, there is evidence that emerging technologies and the Internet are essentially changing how we receive information and how people, and especially young people, learn and memorize. However, due to the limited experimental data available (most of the existing evidence comes from small-scale neuroimaging studies) and the lack of consensus among experts (Choudhury & McKinney, 2013) we might well affirm that technology and the Internet are likely to have both positive and negative effects on the cognitive development of children.

For instance, Carr (2011) has indicated that in the same way reading has developed our imagination and increased our ability to concentrate, the Internet is negatively affecting these capabilities, while reinforcing our multitasking abilities and our capacity to rapidly scrutinize information.

Some of the benefits identified by researchers regarding the use of ICT are as follows (Taylor, 2012), (Shirky, 2010):

- Improves visual skills and spatial capabilities
- Boosts multitasking abilities
- Increases problem-solving abilities
- Encourages collaborative interaction May improve reaction times (for example thanks to the use of video games)
- Improves pupils' motivation

Some of the concerns raised by researchers and academia are as follows (Spitzer, 2012):

- Reduction of concentration capacities and ability to think deeply (generate wisdom)
- Diminution of memory
- Decline of the quality of personal relationships (generation of superficial relationships)
- Generates risks associated with cyber mobbing and bullying

- Risks of technology overuse: addiction
    - Sleep disorders
    - Anxiety/depression
    - Increase of sedentary habits (health related problems)
    - May increase aggressive behaviours

In the cited neuroplasticity studies, researchers argue that the negative effects of ICT particularly influence the cognitive development of infants and young children. The cerebral deterioration caused in the long-term by the intense or excessive use of digital technologies and the Internet is known as "Digital Dementia". The term was coined in Korea in the 1990s and popularised by Dr. Spitzer in 2012; it describes how digital technologies are atrophying our brains because they are limiting the way we use them (Spitzer, 2012).

One popular example is the use of the Internet to access information (for example by using Google). The possibility of accessing any information anytime, anywhere, through a mobile device is affecting our memorizing capacities – we no longer need to memorize much information – and these capacities are essential for the development of critical thinking and knowledge. We now rely on external "memories" (the cloud or a hard disk) and not on the "local" memory of our brain (Sparrow, Liu, & Wegner, 2011). On the positive side, some authors think that this might free resources for new mental activities or capabilities (Wegner & Ward, 2013). What some identify as being harmful effects of technologies, others see as potential distinct advantages; consequently, neuroscientific knowledge should be used carefully when guiding public interventions in education (Choudhury & McKinney, 2013).

2.2. Technologies

In analysing the effect of technology on learning and teaching, it is important to understand the main technology trends affecting the educational environment. These trends are grouped into four categories: enabling technologies, cloud technologies, devices and technical support. Enabling technologies refer to the basic elements that make it possible to provide services, namely connectivity, local area networks, and technical support, to schools, universities, companies and households. Cloud is another trend that deserves specific consideration. Most of the services are shifting to the network and are no longer locally provided. Eventually, the evolution of electronic devices and how citizens access on-line services through these devices will shape new learning services provided through the network.

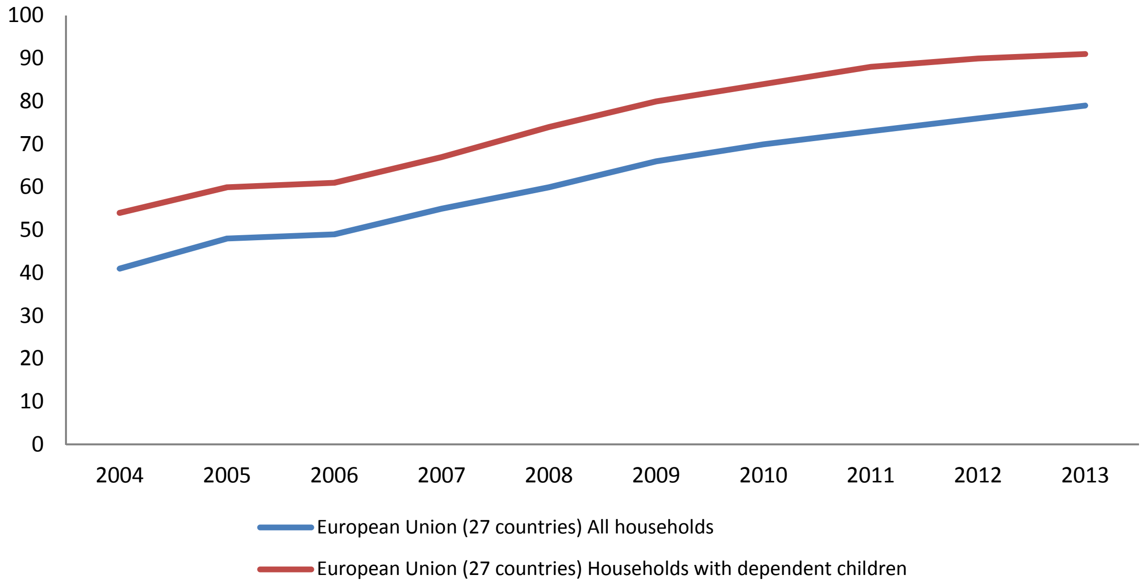
2.2.1. Enabling technologies

2.2.1.1 Fixed connectivity

There is a clear trend towards high penetration rates of broadband Internet access among households in Europe. In fact, broadband connectivity among households has substantially increased over the last 10 years. While in 2004 only 15 per cent of households had broadband Internet access, in 2013 this figure increased to 76 per cent; moreover, it is reaching saturation level among companies (Eurostat, 2014e). Globally, the average speed of broadband access is 16 Megabits per second (Mbps) and it will triple in 2018, reaching 42 Mbps (CISCO, 2014a).

These penetration rates can be considered sufficient for citizens to properly use educational resources through the Internet. Problems regarding specific population groups left behind will be further considered. When analysing the situation from an educational and learning perspective, it is interesting to study the level of connectivity at households with dependent children as well as at schools. Regarding families with dependent children, the results can be seen in Figure 2. As expected, families with dependent children have higher levels of Internet penetration, reaching a remarkable 91 per cent in 2013 among European countries (Eurostat, 2014d). There are two main reasons for this higher rate: young people press their parents to have Internet connection at home, and parents are aware of the benefits of having Internet access for the development of their children.

Figure 2: Percentage of households with broadband Internet access



Source: (Eurostat, 2014d)

With regards to European schools, in 2012, the majority had broadband connectivity (between 2 and 30 Mbps), compared to less than three-quarters of schools in 2006, although between 4 and 8 per cent of students still lacked access to broadband connectivity. However, the next challenge is the adoption of ultra broadband connectivity - up to 300 Mbps - provided by fibre optic technologies (E. Schoolnet & Liege, 2013, p. 33). This figure is very low in Europe. As of 2014, less than 10 per cent of students in European schools had connectivity higher than 30 Mbps, while South Korean schools had 100 per cent of broadband penetration at an average speed of 118 Mbps (BusinessWire, 2014). The current lack of ultra broadband connectivity at the school level can seriously hinder the adoption of new learning methodologies by not allowing the delivery of high definition contents and the effective use of cloud technologies and services.

2.2.1.2 Mobile connectivity

Broadband mobile connectivity is becoming increasingly important. Mobile traffic in 2013 was 18 times larger than total Internet traffic in 2000 — accounting for nearly 18 exabytes; further, it is expected than this traffic will grow 11-fold between 2013 and 2018. During this same period, mobile data traffic is expected to grow three times faster than fixed traffic (CISCO, 2014a). Mobile speeds more than doubled in 2013 compared to 2012, reaching an average of 1,387 kilobits per second (CISCO, 2014b).

New technologies are being deployed that substantially improve the speed and capacity of the mobile networks. 4G/LTE (Long-Term Evolution) is the next stage in mobile connectivity that allows speeds up to 100 Mbps, 10 times higher than the speed provided by 3G/UMTS (Universal Mobile Telecommunications System) and 3.5G/HSDPA (High Speed Downlink Packet Access) technologies while reducing the cost per megabyte (MB) up to 10 times. It will help to reduce the gap in performance between fixed and mobile networks making availability of high quality contents anywhere and anytime a reality. However, 4G connections represent less than 3 per cent of mobile connections today, although they account for 30 per cent of mobile data traffic. It is important to note that in 2013, only 55 per cent of mobile traffic went through mobile networks, while 45 per cent of mobile traffic was offloaded onto fixed networks through Wi-Fi or femtocells[2] (CISCO, 2014b). This figure is expected to grow, and by 2018, 50 per cent of the mobile traffic will be offloaded into the fixed networks. It makes fixed networks an adequate and necessary complement of mobile networks. The total traffic of mobile and Wi-Fi networks is still lower than in wired networks (39 per cent). However, in 2018, it is expected that the total mobile traffic will exceed traffic from wired devices, accounting for 61 per cent of IP traffic (CISCO, 2014a).

From an educational perspective, mobile networks provide much greater flexibility to deploy new ways of teaching and learning, and to overcome physical and time barriers with regards to accessing education. The Internet is, without a doubt, becoming mobile and educational technology will follow.

2.2.1.3 On-site infrastructure

The infrastructure at the school and university level provides the link between the Internet, school IT services and user devices. The on-site infrastructure is crucial to the provision of services in an environment of low-speed connectivity. However, broadband connectivity and cloud services are shifting on-site infrastructure towards a mere link between the Internet and the devices. Although having adequate on-site infrastructure is a key factor to the effective integration of technology in the education process, only two thirds of students in European schools have access to a Local Area Network (LAN). Schools generally have both wired and wireless networks (E. Schoolnet & Liege, 2013, p. 47). Having wireless network provides the required flexibility in the school environment and allows connecting mobile personal devices.

2.2.2. Cloud

Cloud computing refers to shifting technological services from traditional locally owned and managed IT infrastructures towards services delivered on demand through the network from a shared infrastructure provided and managed externally by a third party. The essential characteristics of cloud computing are: on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service (Mell & Grance, 2011, p. 2).

Traditional IT infrastructure is not flexible enough to cover the evolving demands of users. Rigid and established expensive infrastructures become obsolete while being unable of keep pace of the increasing demands of users and managers. Local IT managers and technicians lack the skills and knowledge required to provide complex services. This explains the growing market of cloud services where a highly specialized third party provides these services in a smooth and seamless way. Resources are available when and where they are needed. In fact, enterprise spending on cloud services is expected to triple between 2011 (78.2 billion US dollars) and 2017 (projected to be 235.1 billion US dollars) (IHS, 2014). Cloud services can be provided using

> The Higher Education Funding Council for England (HEFCE) launched a program in 2011 to promote the development of shared cloud services among universities and colleges in England. An investment of up to 10 million pounds in cloud computing, shared IT infrastructure, support to deliver virtual servers, storage and data management applications was committed to promote a collaborative and cost-effective way of using technology in a time of pressure on university resources (HEFCE, 2011).

[2] Femtocells are small cellular telecommunications base stations that improve mobile coverage inside buildings; they are usually connected to the operator's infrastructure through the Internet.

different models: Software as a Service, Platform as a Service or Infrastructure as a Service (Mell & Grance, 2011, p. 3)[3].

In the educational environment, it provides several benefits: allows for the fast provision of new applications, contents and services in the new mobile environment to keep track of the increasing demands of learners, teachers and managers; fosters the standardization and interoperability of services; eases the scaling of services; reduces the required initial investment in an environment of budget costs; and allows public managers to draw upon complex innovations without deep unfeasible changes in their team structure and composition (Mansuri, Verma, & Laxkar, 2014). Employees' and personal use of cloud (CDW LLC, 2013, pp. 30-31) and the increasing growth of high demanding traffic in the mobile (CISCO, 2014b) and fixed networks is making educational organizations move faster towards the cloud. In 2018, cloud traffic in the mobile networks is expected to increase to 90 per cent compared to 82 per cent in 2013. Cloud traffic will be mainly video and audio streaming, online gaming, social network traffic, and on-line storage, categories closely related to the educational environment (CISCO, 2014b, p. 15).

Eventually, cloud computing will have "the power to fundamentally change how education stakeholders' cooperate and collaborate, substantiates the ability of technologies to alter the whole system of education" (Koutsopoulos & Kotsanis, 2014, p. 58).

Those are the reasons why the market of cloud computing in education is expected to grow from 5.05 billion US dollars in 2014 to 12.38 billion US dollars by 2019 (marketsandmarkets.com, 2014). There are several cloud models that can be used by educational organizations including: private clouds, virtual private clouds[4], public clouds, community clouds and hybrid clouds (Mell & Grance, 2011, p. 3). In choosing the best model for a specific service, several factors must be taken into account, such as political and technical feasibility, legal and security issues, time to market, strategic requirements, main objectives, previous infrastructure, investment and operational costs, and current skills and knowledge within the organization (CISCO, 2012).

While new innovative specialised cloud services are expected to arise in the medium-term, the first steps go towards using out-of-the-box services that are widely used in the personal life of teachers and learners, such as Google apps for education, Dropbox or Skype (L. Johnson et al., 2014).

2.2.3. Devices

The connected society has shifted from fixed connectivity where a personal computer was low-speed connected to the Internet in a fixed physical place towards an embedded multimedia connectivity characterized by fast and persistent connection and ubiquitous access (Katz, 2008). Although in 2013 only 33 per cent of the traffic was generated by non-PC devices, in 2018 it is expected that this traffic will increase to over 50 per cent of the total traffic (CISCO, 2014a). A plethora of new mobile devices have arisen that is displacing computers as the main technological device used by citizens and companies to connect to the network, and the trend is increasing as shown in Figure 3. While in 2013 8.89 per cent of the devices sold worldwide were desktop computers, the projected share in 2018 is expected to shrink to 4.9 per cent. The same phenomenon is occurring for laptops, whose market share will shift from 11.59 per cent in 2013 to a estimated 6.9 per cent in 2018 (IDC, 2014). Smartphones are the main beneficiaries of this shift. Mobile devices in 2013 grew to 7 billion, up from 6.5 billion in 2012 and smartphones accounted for 77 per cent of that growth (CISCO, 2014b). The share of smartphones

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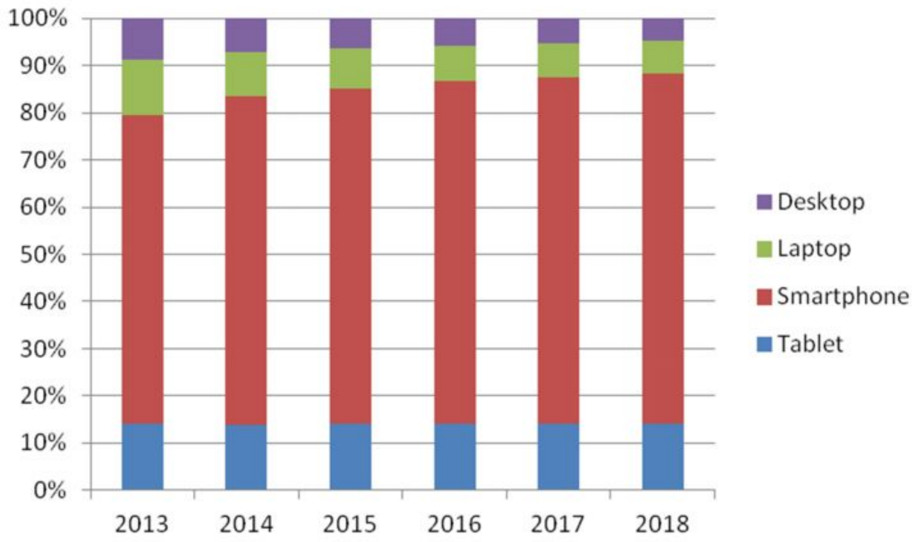
[3] Software as a Service relates to providing end-user applications through the Internet, Platform as a Service refers to providing basic software, such as database systems or application servers; and infrastructure as a Service involves having remote access to physical resources, such as servers and disk storage.

[4] Private clouds are based on infrastructures that are not shared with other organizations, while virtual private clouds are private resources allocated within a public infrastructure.

will continue growing; it is expected that, in 2018, they will account for 74.1 per cent of the total connected devices.

Figure 3: Worldwide smart devices market share

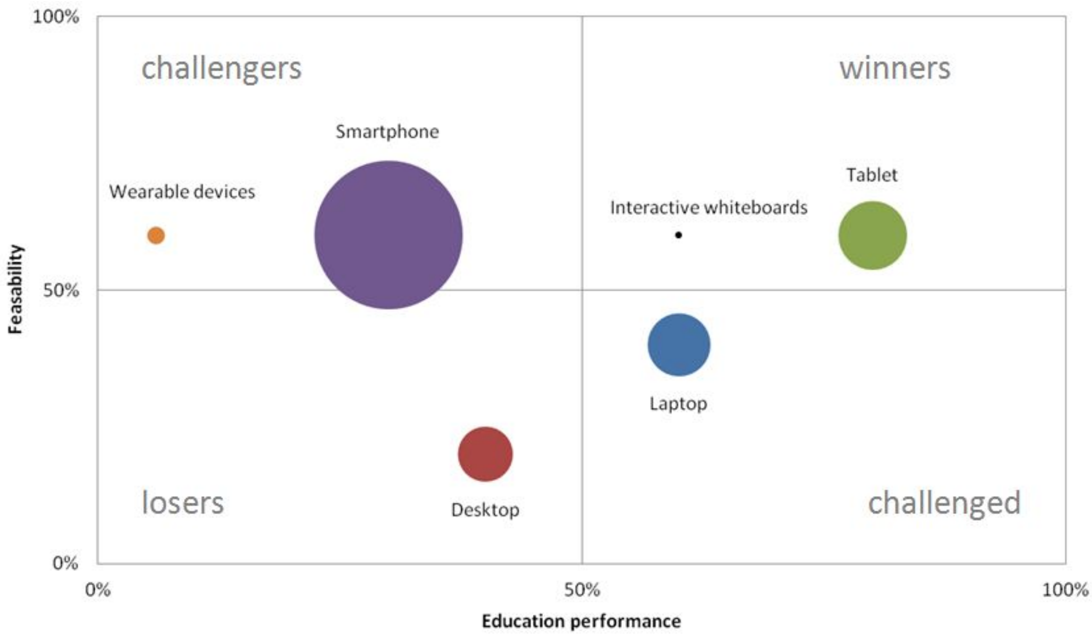


Source: (IDC, 2014)

With regards to mobile devices, there is a clear trend towards a substantial growth of smartphones compared to non-smartphones, a 6-fold increase of tablets, and a similar increase of other Machine to Machine (M2M) devices, including wearable devices. The increasing market share of smart devices and connections will be particularly relevant for the US and Western Europe. It is expected than in 2018, the share of smart devices and connections in Western Europe will be 83 per cent in comparison to 45 per cent in 2013; moreover, the share of smart devices is expected to reach 51 per cent in Central and Eastern Europe by 2018 in comparison to 15 per cent in 2013. Surprisingly, in this environment of personal mobile devices, the majority of teachers and students continue to access digital resources at schools through a fixed computer. On average, the number of students per desktop computer is 7, while the number of students per laptop ranges between 8 and 20, depending on the grade. Currently, laptops, tablets and netbooks in schools only are relevant in five European countries: Denmark, Norway and Sweden at all grade levels, and Spain and Finland at some levels (E. Schoolnet & Liege, 2013, p. 33).

Figure 4 classifies the different devices by two criteria: feasibility and education performance. Feasibility compounds three factors: Total Cost of Ownership (TCO) of the device — including acquisition and maintenance cost, flexibility of use — how easily the device can be installed and moved, and IT capabilities — software and applications that can run on the device and IT performance. Education performance compounds two factors: how easily the device integrates into the education environment — attending physical, functional and performance characteristics — and how confident teachers and students feel about the device. Based on these criteria, the devices are classified as "winners": high education performance and high feasibility, "challengers": high feasibility but low education performance, "challenged": high education performance but low feasibility and "losers": low education performance and feasibility. Information about the number of worldwide shipments in 2013 per type of device is also reflected in the chart through the size of the ball. This information is particularly relevant because electronic devices have a short lifetime, and therefore, current shipments show very clearly the total number of devices in the years to come. Interactive whiteboards are also included in the analysis, although in this case, the size of the ball refers to the total number of interactive whiteboards at European schools.

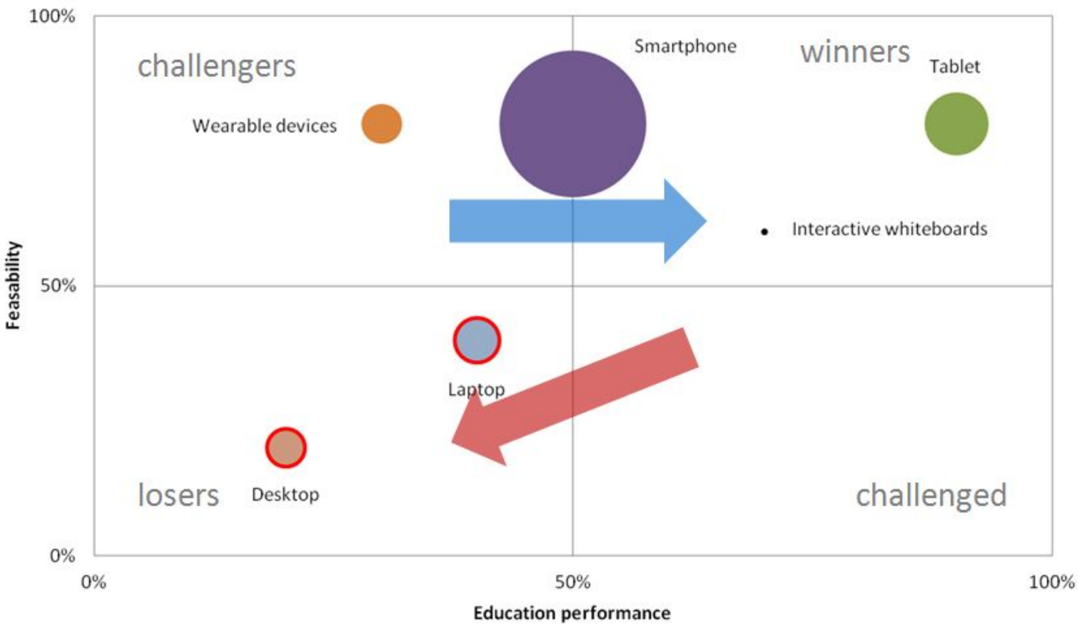
Figure 4: Device strategic positioning in 2013



Source: Compiled by the authors based on (CISCO, 2014b; Gartner, 2014a; IDC, 2014; E. Schoolnet & Liege, 2013)

More interesting is how this situation will likely shift in 2018 as shown in Figure 5. All mobile personal devices will grow in number of shipments compared to 2013 while desktop computers and laptops will substantially reduce their market share. It is expected that in the medium-term, personal mobile devices, such as wearable devices, tablets, smartphones, and phablets (half way between both of them) will play a much more relevant role in the educational environment. Interactive whiteboards are expected to grow in European schools because they foster a smooth way of blending technology and traditional learning. Desktop and laptops are likely to reduce their presence in the education environment. This shift will foster more flexible and adequate uses while keeping the cost low, thus opening a world of new possibilities.

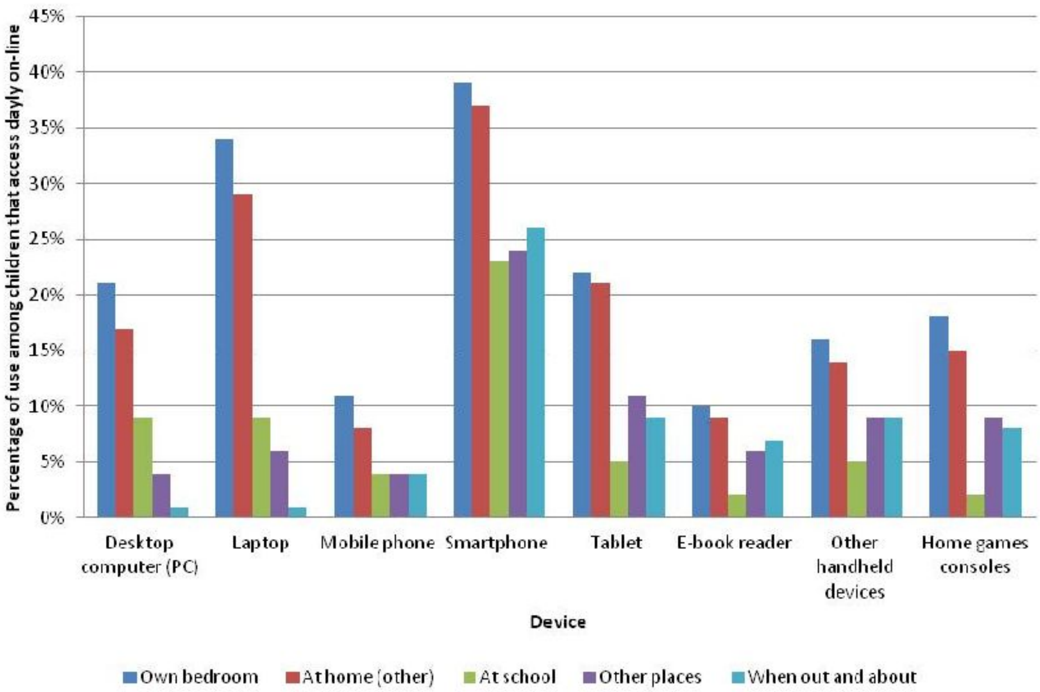
Figure 5: Device strategic positioning in 2018



Source: Compiled by the authors based on (CISCO, 2014b; Gartner, 2014a; IDC, 2014; E. Schoolnet & Liege, 2013)

There is evidence that supports this trend towards a mobile ecosystem. Observing children aged between 9 and 16 years in four European countries (Denmark, Italy, Romania and the UK), the most used device for Internet access on a daily basis is a smartphone followed by a laptop and a tablet (Mascheroni & Ólafsson, 2013, p. 11) (see Figure 6).

Figure 6: Devices used to access the Internet daily at different locations

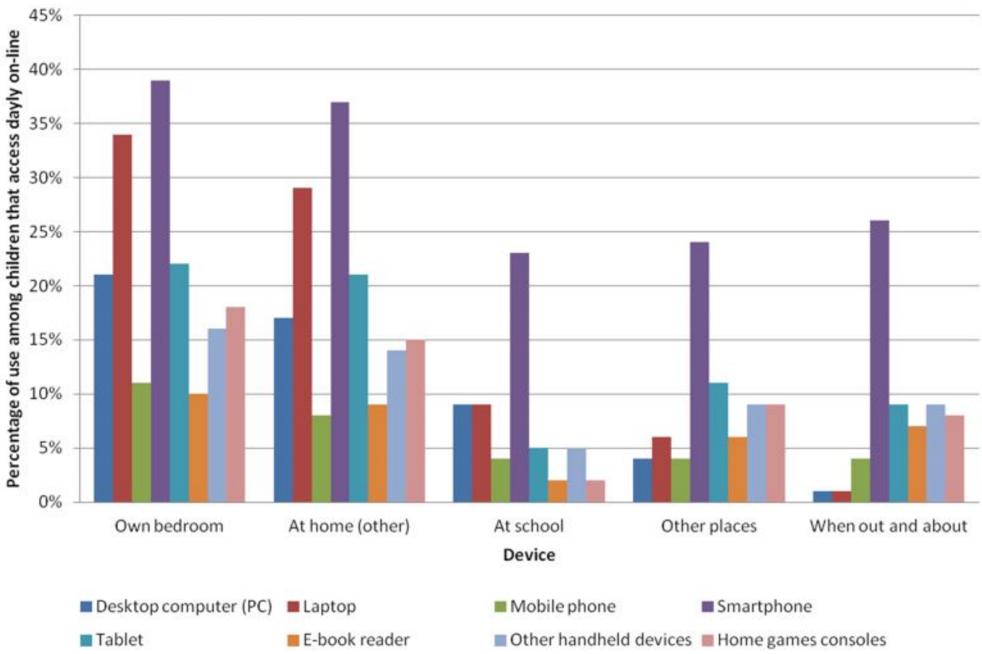


Source: Compiled by the authors based on (Mascheroni & Ólafsson, 2013, p. 11)

Moreover, when analysing the same information by place, as shown in Figure 7, the gap between school and other places is remarkable, particularly if considering that smartphones are still rarely used for educational purposes at the school.

However, using personal heterogeneous devices in the school raises concerns about the interoperability of contents and services. New standards should be defined to guarantee that contents and services could run on any available device and platform. Moreover, these standards should be open to avoid market dominance and monopolistic behaviours that could end up making users worse off.

Figure 7: Devices used to access the Internet daily by location



Source: Compiled by the authors based on (Mascheroni & Ólafsson, 2013, p. 11)

2.2.3.1 Desk computers

Desk computers are most frequently used in schools for Internet access; the penetration has dramatically improved over the last 15 years. In 2000, on average, there was one computer per 20 students aged 15; in 2011 there was on average one computer per two students at the secondary level, and one computer per 4 students at the 4th grade, with only 3 countries having more than 6 students per computer (Eurydice, 2011, p. 75). In fact, the ratio of students to computers has been used as an indicator of ICT penetration, although the presence of computers alone does not guarantee that technology is properly used for learning. Along with the average growth in the number of computers per students, disparities in this indicator between schools have also substantially been reduced in the last years in most European countries.

2.2.3.2 Laptops

Using laptops in classrooms has several benefits. It allows fostering more flexible teaching models while promoting the sharing of devices among students and classes. Another potential benefit is that laptops encourage "Bring your own technology" policies, where the students take their own laptops to school. While this option would substantially increase the number of laptops in classrooms, it raises concerns about inequality. These policies should go hand-in-hand with providing computers to students of low-income families.

2.2.3.3 Tablets

On average, a tablet generates 2.6 times more traffic than a smartphone (CISCO, 2014b). Although the current number of smartphones is much higher than tablets, and this trend is unlikely to change in the medium-term, the total traffic generated by tablets is growing at a faster pace. Another important trend is that borders between tablets and smartphones are blurring. Although it is likely that both devices will coexist in the next few years, the market share of smartphones with larger screens (phablets) and smaller size tablets is making it increasingly difficult to differentiate between both types of devices. Due to their improved screen and IT performance, tablets provide higher capabilities compared to smartphones, which makes them more adequate devices for education purposes.

2.2.3.4 E-readers

E-readers could act as substitutes for books. The cost of e-readers is quite low and they enable textbooks to be offered in digital format, thus potentially saving money, room and lighting the load on children’s shoulders. However, e-readers have not succeeded in the educational environment, mainly due to a lack of applications and multimedia capabilities. In fact, very few e-readers are reported in European schools; in 2013, there were 100 students per e-reader in almost all countries (E. Schoolnet & Liege, 2013, p. 41)

2.2.3.5 Smartphones

Smartphones are the rising star of Internet traffic. The average traffic generated by a smartphone is expected to grow 5 times during 2013, reaching an average of 2.7 GB per month (CISCO, 2014b).

This phenomenon is particularly significant for students. Cell phones are common used by students outside the classroom. However, while most students have a cell phone, its use is usually restrained in the classroom environment on account of behavioural concerns. In fact, modern cell phones, namely smartphones, are small computers that would facilitate the straightforward and virtually free implementation of the 1to1 model (Norris & Soloway, 2009). Currently between 28 and 46 per cent of European students use their own cell phone at school for learning purposes (E. Schoolnet & Liege, 2013, p. 55). It is very likely that teachers are not encouraging the use of cell phones for learning purposes.

2.2.3.6 Game consoles

Game consoles are extensively used by young populations, although there is a clear trend towards smartphones replacing game consoles as the preferred gaming device. It is suggested that computer games have the potential to enhance skills and knowledge while increasing engagement and motivation (Passey, Goodison, & Britain, 2004; Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009). However, despite the evidence which confirms the benefits of using game consoles in the classroom (Miller & Robertson, 2011) and the increasing number of schools using video games, there is a lack of using game consoles for learning purposes in core academic subjects (Kirriemuir & McFarlane, 2003).

2.2.3.7 Wearable devices

A wearable device is an electronic system that can be worn by a person; it possesses processing and communicating capabilities by either using its own cellular capability or through another device, such as a Wi-Fi router or a smartphone. These devices can adopt different forms such as glasses, watches, wallets, clothing, etc.

Although a number of these devices are still small, new technologies that allow compressing vast computing, storing and communicating capabilities in tiny components are pushing feasible designs into the markets. Most of the big brands are introducing watches, glasses and other devices that, only a few months ago, seemed only feasible in science fiction. The growth of applications, such as location-based services and augmented reality, fostered by the apps ecosystem is further fuelling the utility of these devices. However, these devices are still at a nascent stage and their potential use in the educational setting is still unclear. However, the trend is clear and in 2018, it is expected that there will be more than 177 million wearable devices globally, compared to 22 million in 2013; moreover, traffic will grow 36-fold reaching 61 petabytes per month by 2018 (CISCO, 2014b). Wearable devices will make computing and connectivity very pervasive in our daily lives; they will affect many aspects of life including education.

2.2.3.8 Interactive whiteboards and projectors

Interactive whiteboards (IWBs) and projectors are increasingly gaining momentum in the school environment. There are some benefits to using these devices in the classroom. It is a very low-disruptive technology because it fosters a smooth transition from “analogical” to digital blackboards. The educational methodologies can be easily adapted to these new devices and teachers feel comfortable using them in the classroom environment. It offers an easy path to discover new ways of blending technology and traditional teaching. However, the number of IWBs it is still low in European schools, with approximately 100 students per one IWB; in addition, teachers and school leaders consider that lack of IWB at European schools hinders ICT use. Only 30 per cent of students at grade 8 and 20 per cent at grade 11 use an IWB at least once a week. Most of the IWBs are located in classrooms, however, some can be found in labs, particularly in the context of vocational education; very few are available in libraries. The good news is that there are twice as many beamers than IWBs, creating an opportunity to substantially increase the number of IWB while keeping costs to a minimum (E. Schoolnet & Liege, 2013, pp. 9,19).

2.2.4. Technical support

The lack of adequate technical support is considered one of the most relevant factors hindering the effective introduction of technological resources in the educational environment, affecting up to 50 per cent of students in some European countries (Eurydice, 2011, p. 84). While governments are concerned about providing computers and equipment to schools, once the equipment is provided, governments are less concerned about providing adequate support and maintenance, making technical maintenance a school issue. Most of the time schools are forced to maintain the equipment despite lacking the necessary skills or budget. Between 75 per cent and 94 per cent of students, depending on the grade, are in schools where the school staff maintains the ICT infrastructure. In some countries, support for higher educational units is sometimes outsourced to the private sector (E. Schoolnet & Liege, 2013, p. 50).

2.3. Educational contents, tools and services

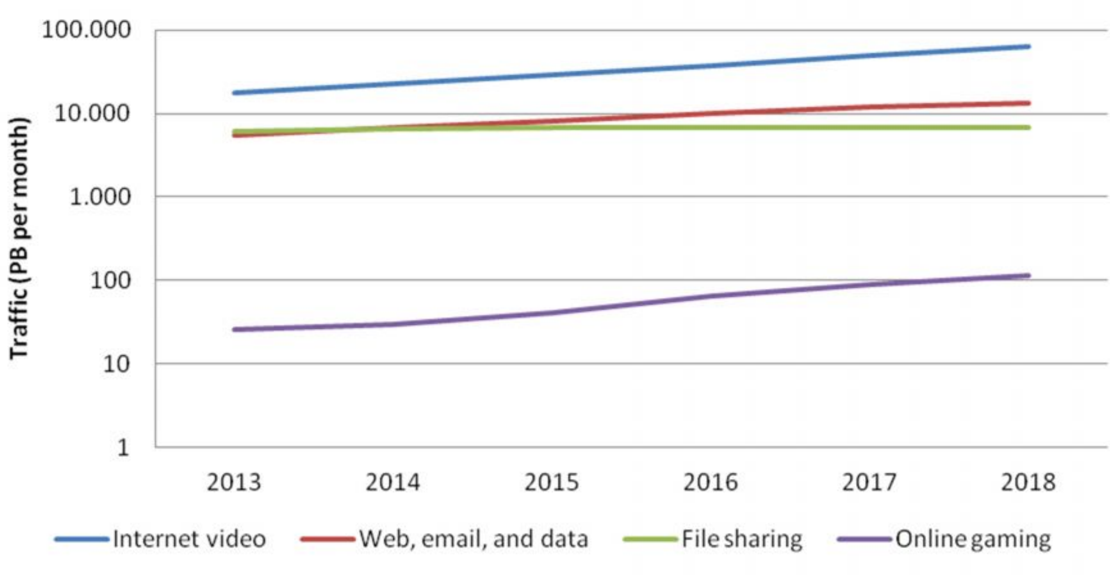
A new myriad of innovative contents, tools and services has been deployed as a result of the fast evolution of the enabling technologies. Ultra broadband connections and services migrating into the cloud allow sharing information and contents and working in collaborative environments. Ubiquitous access promoted by faster mobile networks and intelligent mobile devices create new ways of communication anywhere, anytime.

2.3.1. eContent

Over the last twenty years, the content industry has undergone profound changes. Prior to the eruption of digital means, the content industry was a mature sector characterized by high entry barriers due to high costs of production and distribution. The production of contents was oriented to specific groups of the population and the distribution was segmented geographically. However, digitisation substantially changed the industry by decreasing the production costs and creating global markets where the contents can be easily provided worldwide from a single location. Decreasing production costs are blurring the barriers between producers and consumers. The Internet creates an environment where specific users' preferences can be easily met by personalized services provided by new entrants that draw upon big data technologies to strongly personalize contents and services. Traditional media, such as newspapers, TV, and advertising, are seriously challenged by the new entrants, casting doubt on their very survival. New digital contents, such as social media and application ecosystems, are fundamentally shaping new ways of sharing services, contents and information.

In fact, digital contents are becoming the most relevant source of traffic on the Internet. Globally, content delivery networks carried 36 per cent of the total traffic in 2013; this is expected to increase to 55 per cent by 2018. IP video traffic already accounts for over 66 per cent of the total traffic. By 2018, it is expected that the total video traffic will reach over 80 per cent (CISCO, 2014a), massively exceeding web and file sharing data as can be seen in Figure 8. As an example of the increasing relevance of video traffic, mobile video traffic exceeded 50 per cent of total mobile traffic in 2012, and further growth is expected. In 2018, more than two-thirds of mobile traffic is excepted to be video traffic (CISCO, 2014b).

Figure 8: Traffic volume per month depending on the source (2013-2018)



Source: Compiled by the Authors based on (CISCO, 2014b)

The Spanish association of publishers (ANELE) has launched a platform to provide a unique access point to the educational digital contents of the different publishers. The main goal is to provide an easy way for the educational community to access the digital catalogue of high quality contents and materials. Teachers and school leaders can easily choose the material that best fits the needs of their schools. The platform is intended to guarantee neutrality, flexibility and standardization so the materials can be easily adapted to different technical platforms and devices while preserving the property rights (ANELE, 2013).

In this environment new digital entrants, mainly from the US, are driving the change by shaping a sector with new rules, while the legacy stakeholders are trying to redefine their role; moreover, traditional regulations are proving to be ineffective. In fact, traditional stakeholders are reluctant to fully embrace digitalisation of contents, as arising business models benefit more new entrants in the value chain, thus restraining a legal valuable offering while promoting on-line piracy. The main patterns of the new industry include: high commoditization of contents, lack of competition in innovative market proposals, convergence of contents regardless of their original media, and creation of new ecosystems where consumers, producers, *prosumers*[5], and advertisers live together in an environment controlled by the owner of the platform.

The challenges for policy makers in Europe are: enacting local regulations to solve global problems, particularly when considering the potential monopolistic market dominance of large American and Asian digital players such as China or Korea, avoiding the digital content gap that would leave illiterate populations behind in this connected environment, supporting legacy European industry to evolve towards digital business models without hindering the growth of the sector, fostering innovation among European companies to play a more substantial role in this market, and drawing upon researches, industry and community to maximize the benefits using digital contents to improve public services, particularly education.

These trends also apply to the sector of educational contents. Book publishing in Europe is the most important cultural sector, accounting for more than 23,000 million euros in revenue each year; in addition, 6 to 8 out of the 10 mayor publishing groups are European (ANELE, 2013, pp. 2-3). Most of these groups publish educational books, such as Pearson (the UK [the biggest in the world]), Hachette (France) and Planeta (Spain). There are several market segments: K-12 textbooks purchased by families or educational bodies, other complementary materials purchased by families, higher education books, vocational training books and scientific journals. K-12 textbooks account for 35-40 per cent of the market (ANELE, 2013, pp. 2-3). However, the Internet is changing the traditional industry of educational contents. No more than two decades ago, textbooks were almost the only way to provide contents in the educational environment. Today, the textbook industry is challenged by the Internet through several factors: new ways of commercialisation by purchasing used or rental books, an increased demand for digital books that reduce the revenues of legacy publishers, and the most relevant in the medium-term, the emergence of new competitors, both for-profit businesses with disruptive innovative business models, and even more transforming, the Open Educational Resource (OER) movement (Band, 2013). The established stakeholders are trying to adapt to this new environment with mixed results. It is pretty clear than the new market will be smaller for legacy providers; as a result, they are hindering the transformation process.

[5]*Prosumer* is a term first put forth by Alvin Toffler in 1980; it is formed by the contraction of the words "producer" and "consumer". It refers to the growing importance of consumers as creators or producers of content and information in the digital era.

These trends create amazing opportunities to increase the availability and quality of educational contents while reducing the cost. However, new challenges arise for policy makers, such as guaranteeing the quality of the materials, preserving equality, defining standards that allow the interoperability of contents though different devices and platforms, and finding a healthy balance between commercial for-profit producers and open resources developed by the community. The for-profit industry of educational contents employs thousands of workers in Europe, and it is important to find a way in which this industry can shift its business models to create new sources of value without hindering the opportunities fostered by the digital environment.

Private foundations such as the Bill & Melinda Gates Foundation and the William & Flora Hewlett Foundation are supporting the development of OERs. The American Recovery and Reinvestment Act in 2009 included 2.000 million US dollar grants to develop educational and training materials released under a Creative Commons license by Community Colleges (Band, 2013).

2.3.1.1 OER: open learning environments

There is a movement towards making educational contents and resources, most of them developed by teachers, freely available in what is called the OER movement. The term was born in 2002 at a conference hosted by UNESCO. Since this time, the OECD has further redefined the concept as "digitized materials offered freely and openly for educators, students and self-learners to use and re-use for teaching, learning and research" (Hylén, 2007, p. 1). There is some controversy about the meaning of the concepts behind OER. "Open" is related to free of charge, although some restrictions in its use can apply. "Educational" should be understood in a broad sense, not only involving formal learning materials, but also other material that can eventually be used for formal or informal training purposes. Eventually, "resources" can involve any kind of material, although OER usually refers to digitalized materials (Online Digital Learning Working Group, 2014). In fact, it is the connected society, which fosters the use of these available contents and a user-led approach. OER includes learning content — such as open books, videos, presentations, and full courses, and other tools and implementation resources — such as lesson plans and tests. Today thousands of contents, lectures, courses, class activities, and assessment tools are available in the network for free. Sharing these contents using Creative Common Licenses makes these resources widely available in an ordered manner (Online Digital Learning Working Group, 2014). However, successfully using OERs may be a challenging task. A lack of transparency about the rights and obligations for using OERs can deter producers from developing contents and consumers from using them. It is difficult to guarantee the quality and completeness of contents developed by the community. It may be challenging for teachers and students to find the right contents. In fact, teachers tend to use resources recommended by other colleagues. Deploying trustful platforms of OERs that catalogue the contents, establish clear property rights, and assure their quality through a peer-reviewed process can help to overcome these problems.

The OER movement is growing very fast thanks to large institutional and community support; further, the increasing number of OERs available on the Internet is fostering new ways of teaching and learning. OERs are usually funded by foundations and government agencies. Most of the OERs are in English and are related to higher education contents.

In 2014 the ***Opening Up Slovenia*** initiative was launched; it was the first national-level action implementing the principles of the European Commission's Opening Up Education initiative. Slovenia has become a testing and experimental field for educational technologies at all educational levels; the aim is to develop a framework for innovation and research in the educational field. Activities and experiments cover all areas of open education including: 1) advanced technologies and open learning environments, 2) open educational resources, and 3) means of open connectivity and innovation.

In Europe, the "Opening Up Education" initiative fostered by the European Commission is proposing actions to promote more open learning environments and increase the quality and efficacy of educational contents and materials for increasing competitiveness and employment. The European Commission intends to support the OER movement in Europe through several actions: promoting and sharing best practices, providing financial support, promoting public-private partnerships and making recommendations, thus avoiding fragmentation and creating economies of scale (EC, 2013c).

2.3.2. Apps in education

Apps or applications are software programmes designed for mobile devices. These software programmes perform different functions, such as communication, data storage, information processing, etc. The number of apps has grown exponentially over the last 5 years to largely surpass 1 million apps available both in the Apple store and in the Google play store with more than 135 billion of cumulative downloads (Statista, 2014). The app ecosystem is one of the largest technological successes, growing faster than any other previous service. South Korea, China and Japan are clearly the fastest growing mobile markets with rates higher than 200 per cent; in 2013, South Korea experienced a 759 per cent growth, while more established European markets grew at much lower rates (Distimo, 2013b).

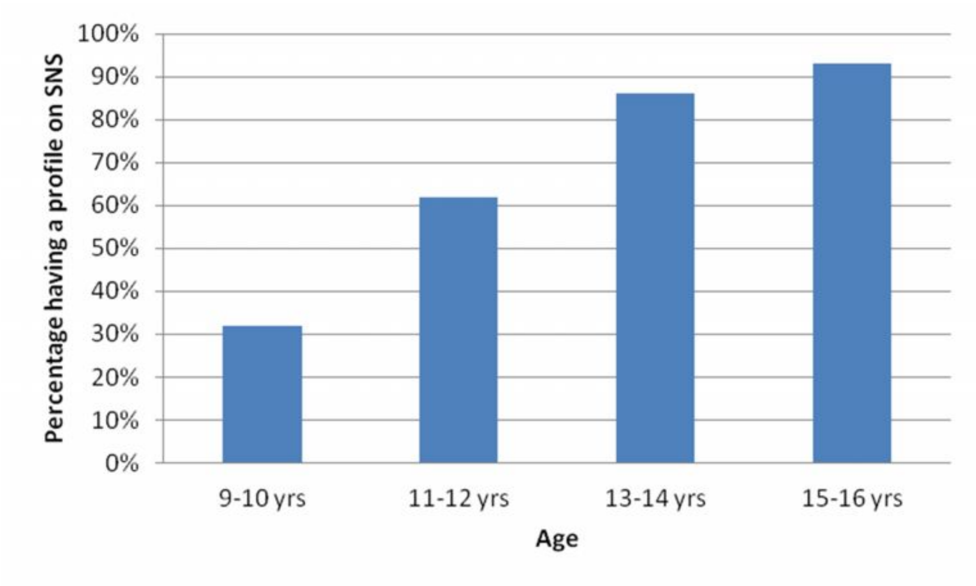
Apps are expected to be a relevant and growing media to deliver educational contents and services (Shuler, 2012, p.3). Apps have proven to be very successfully in providing highly appreciated services in a wide range of fields, and their use on formal education is likely to represent a vast and largely untapped resource that will explode when mobile devices become a reality in daily school life. Educational apps are the second largest category in the Apple store, accounting for 10.36 per cent of the total number of apps; they are the sixth largest category in Google Play store, accounting for 6.1 per cent of total apps (Statista, 2014). Download of educational apps for iPads in September 2013 ranked third, accounting for 6.1 per cent of total downloads (Distimo, 2013a). However, only 14 per cent of current educational apps are intended to be used at schools (Shuler, 2013, p. 19).

However, education apps are facing some limitations and risks, such as a lack of standardization and quality assurance, the "apps divide" that has left those most in need behind, and an inability to protect children from opportunistic behaviours from developers (Shuler, 2012, p. 4).

2.3.3. Ubiquitous social media

Social media creates ubiquitous environments that allow people to interact, communicate, create online communities and share content. Europe has around 300 million active social media users, 66 per cent of which access social media through mobile devices (Kemp, 2014). The use of these tools is particularly relevant among young people. Observing children between the ages of 9 and 16 in four European countries (Denmark, Italy, Romania and the UK), the percentage of children having a profile on social networking sites (SNS) ranges from 32 per cent to 92 per cent depending on their age (Mascheroni & Ólafsson, 2013, p. 22) (see Figure 9).

Figure 9: Percentage of children on SNS



Source: Compiled by the authors based on (Mascheroni & Ólafsson, 2013, p. 22)

Social media, when used in the educational context, permits teachers and student to communicate and access content anytime, anywhere, particularly when accessed in mobility. Their use, in addition to providing ubiquity to the educational process, and thus providing flexibility, can enhance collaboration, participation and creativity thanks to co-creation of content and knowledge (user-generated content) (E. Schoolnet & Liege, 2013).

Social media includes a wide range of channels and contents, however, the most commonly used in education so far are videos and blogs (Johnson, Adams, Estrada, & Freeman, 2014a).

Despite the learning potential of social media and the high penetration of these tools among students, its application in schools is still very low (E. Schoolnet & Liege, 2013). Even in higher education, although students are sophisticated consumers of social media in their personal and professional lives, faculties lag behind in the use of social media in the classroom due to concerns about privacy issues and the integrity of students' submissions (Seaman & Tinti-Kane, 2013).

2.3.4. Online collaboration platforms and services

Web 2.0 technologies have fostered a host of educational tools that allow collaborative work among students and teachers. These tools are usually based on websites where participants can hold on-line communication and discussions, and jointly create contents and materials. These services are provided through different business models, namely "open platforms" developed by the community, "commercial free platforms" where revenues usually come from advertisement, "*freemium*" where a basic set of services is provided for free, and "payment services" which are usually based on a one-time or a monthly fee. These platforms are usually specialized on specific services, such as collaborative searching, collaborative mind mapping, collaborative writing, working as part of a group in collaborative work-spaces, working in shared whiteboards, watching videos and subsequently discussing them, sharing presentations as well as sharing and organizing source code.

Among these services, social media deserves specific consideration. Although social media platforms are not intended for developing collaborative work, the high penetration among specific segments of the population are turning these services into a true collaborative framework where users share ideas and develop new concepts.

In fact, users are building collaborative environments through the simultaneous use of some of these platforms. Users chat using Whatsapp, share pictures in Instagram, share files and documents using Dropbox, Google docs, Github, or OneDrive, and hold virtual calls using Skype. Learning management systems (LMS) and MOOC platforms are also integrating collaborative services in their portfolios, by using proprietary products or open services available in the network.

2.3.5. Data Analytics

The increasing interaction between teachers and learners with web learning tools provides useful information about how teachers and learners are developing within the education process. Analysing this information can lead to creating personalised environments adapted to the specific needs of the students, maximizing their educational performance. Although results of applying data mining techniques to current web-based educational systems seem promising, deeper specialization is still required for educational data mining to become a mature and useful technology (Romero & Ventura, 2007). Nevertheless, the application of this technology in education raises security and privacy concerns that might result in an important barrier to its development. For further information on these questions, see section 6.3.

2.3.6. Learning Management Systems (LMS)

LMS deliver learning contents and services through a unified and holistic environment that includes functionalities such as authentication, class and course management, content delivery, collaboration services and assessment. Strong disparities in the use of LMS at the school level exist among different European countries. On average, 25 per cent of students in grade 4 and 60 per cent in secondary school attend schools with a LMS. However, this figure ranges from 6 per cent to 98 per cent, depending on the grade and country. On average, close to 75 per cent of the students that use a LMS at school can use it from a location other than the school (E. Schoolnet & Liege, 2013, pp. 48,49).

These systems can be based on open source initiatives or on proprietary commercial platforms. The first generation of LMS used a monolithic black-box approach to deliver contents clustered around a course, with limited user tracking. The current generation of LMS are based on open and modular frameworks that allow the integration of third-party products, thus creating an evolving environment. However, these platforms are still more focused on the learning process and the course itself rather than the learner. New service oriented systems are arising that will foster building personalized environments. The new generation of LMS will allow interaction with other systems to understand the context in which the learning process occurs and harvesting open contents —including tools based on gaming, simulation, and advance collaborative services — from external sources to adapt the learning process to the specific needs of the learner. The core of the new generation of LMS draws upon standards[6], such as the IMS Abstract Framework, the E-learning framework and the Open Knowledge Initiative, that define how the different platforms can share information and services (Dagger, O'Connor, Lawless, Walsh, & Wade, 2007).

2.3.7. Virtual assistants

The growing complexity of ICT products and services and the expansion of their use among non-professional users has enhanced the development of the so-called Natural User Interfaces (NUI), which allow users to interact with complex computational tools using the same skills required to

[6] LMS standards are a set of specifications that allow producing reusable e-Learning objects and applications. Objects developed using standard specifications can be easily integrated in the LMS platforms to present them to users in a seamless way.

interact with another human being. As a result, users do not require specific training or previous experience in the use of technology, and they can interact in an intuitive way. The evolution of these kinds of technologies, which include gesture and voice recognition and ergonomic and biometric tools, and its conjunction with artificial intelligence techniques, is already being applied in business areas, such as marketing and customer relations; the technologies are also taking off in the health sector. These tools are normally complemented with human-like avatars to increase their user-friendly character.

The wide possibilities of these kind of technologies has a reflection on the efforts IT companies are putting in the development of these tools: Apple's Siri, Microsoft's Cortana, Nuance's Nina and last year's acquisition of Cognea by IBM Watson Group are clear examples of the potential of these emerging technologies. However, existing solutions have yet to achieve higher levels of personalization, natural language and body language recognition as well as learning and reasoning capabilities to improve their applicability in education. For this reason, intelligent virtual assistant technology's mainstream adoption in education is expected to take place within 5 years (Larry Johnson et al., 2014a). Virtual assistants have the potential to be applied in higher education and lifelong learning; they could boost self-driven learning and ubiquitous learning while reducing costs by complementing the role of teachers.

In 2013, EdX, the MIT and Harvard's MOOCs platform, introduced **Discern**, artificial intelligence software for grading students' works, both with regards to text and numbers. According to EdX, Discern frees professors for other tasks and enables "students to take tests and write essays over and over and improve the quality of their answers. With increasingly large class sizes, it is impossible for most teachers to give students meaningful feedback on writing assignments". Thanks to this new software, students receive immediate feedback (EDX, 2015).

3. NEW WAYS OF TEACHING AND LEARNING

As previously mentioned, learning and teaching technologies cannot be understood as simply using technologies as tools for learning and teaching. ICT have to be understood as an enabler of innovation in education and training in a broader sense. Innovation for learning requires a systemic approach, in which technological infrastructure (connectivity, devices, etc.) is only one dimension. Other dimensions include: content and curricula, assessment, learning practices, teaching practices, organization as well as leadership and values (S. Bocconi, Kampylis, & Punie, 2012).

In the previous chapter, we examined the main technologies impacting education in a wide sense (including infrastructures, devices, services and tools). In the next chapter, *The Role of Stakeholders*, we will briefly analyse the impact of ICT on the various actors involved in the education system including their functions and responsibilities; we will mention the organizational implications as well as the role of leadership and the relevance of values, such as equity. In this chapter, we will focus on the dimensions that relate to the curricula, assessment as well as learning and teaching practices.

Technology *per se* will not perform the change Europe requires to upgrade workers' skills, generate employment and boost competitiveness. The implementation of innovative infrastructures without innovation in the curriculum, the pedagogies and the organization will not bring about significant improvement; in fact, it may even lead to a decline in educational performance.

What do we understand by the effective implementation of technologies in education? What do we mean by improving educational performance? According to the European Commission, the objective is to provide the right skills for employability, and to fill the gap between existing skills and those required to maintain European industry's competitiveness (EC, 2012c). These skills should be the outcome of the learning process.

The most commonly accepted skills for success in the digital era (Ala-Mutka, 2011; S. Bocconi et al., 2012; EC, 2012c) include:

- Creativity
- Critical thinking
- Communication
- Collaboration
- Problem solving abilities
- Entrepreneurship
- Project-based skills
- Information management skills
- Autonomy and strategic skills
- Multiculturalism

These skills are not limited to digital competences, but rather include wider attitudinal aspects of the cognitive development of children (Ala-Mutka, 2011).

Digital tools are crucial for acquiring these skills. However, acquiring these skills requires the effective use of ICT along with the reform of the curriculum, the assessment as well as learning and teaching practices.

3.1. The curriculum and assessment

With limited exceptions, today's curricula at K-12 level are broadly based on the same subjects which have been taught for decades, or even centuries; these include: mathematics, languages, social sciences (arts, history, etc.) and natural science (biology, physics, chemistry, etc.). There is general agreement among experts regarding the need to adapt the curricula to achieve the desired outputs of the educational process, that is, equipping students with the skills required for the digital economy.

Nonetheless, there is no consensus regarding the depth of this reform. Some authors argue that the curricula should be reformed to include and stimulate further creativity and innovation, and which incorporates a more experimental, project-based and real-world problem solving approach (S. Bocconi et al., 2012). Other authors maintain that a total review of the content is required. For example, Prensky (2014) proposes to entirely overcome the traditional "subjects" structure of the curricula and identifies four crucial areas where the new curricula should focus: (1) Effective Thinking, (2) Effective Action, (3) Effective Relationships and (4) Effective Accomplishment. Prensky argues that these top-level skills should be the core of education; importantly, these skills include sub-categories, for example effective thinking includes critical thinking, mathematical skills, scientific thinking, creativity, and problem-solving, while effective relationships include communication and collaboration, empathy, ethics, citizenship and conflict resolution.

Along with the reform of the curricula, a review of the assessment procedures is required. If the output of education is different, the way in which it is assessed should be modified to truly judge if the objectives are being achieved.

3.2. Learning and teaching practices

Bocconi et al (2012) have conceptualized a systemic approach to truly innovate teaching and learning practices and ensure the effective integration of technologies. They have developed the term "creative classroom" (CCR), which they define as the "*innovative learning environment that fully embeds the potential of ICT to innovate learning and teaching practices in formal, non-formal and informal settings*". Learning practices refer to the way in which learners engage in the learning process and teaching practices refer to the way in which teachers support learners during this process. In a CCR, teachers must adopt the role of facilitators or coaches and the experience of learning for students should be flexible, personalised and fun (S. Bocconi et al., 2012).

In the following sections, we briefly review the most relevant trends regarding learning and teaching practices.

3.2.1. mLearning

Mobile Learning or mLearning is the educational process that takes place through mobile devices. Most definitions of this learning practice restrict the definition of mLearning to the educational tools and contents accessed on handheld devices; as a result, they exclude the concept of those learning activities developed on laptop or netbooks (Ambient Insight, 2014). According to UNESCO, mobile devices as those "that are digital, easily portable, usually owned and controlled by an individual rather than an institution, can access the Internet, have multimedia capabilities, and can facilitate a large number of tasks, particularly those related to communication" (UNESCO, 2013).

mLearning allows learners to learn anytime anywhere, inside or outside the classroom. Ubiquity, accessibility and communication are key elements of mobile learning.

As it is a concept which centres on the means for learning rather than on educational content or methodology, it is used as the base for more innovative teaching and learning practices, such as personalised, flipped or seamless learning; moreover, it has the potential to improve access to education in countries with low access to quality schooling. For example, it has exceptional potential in developing countries, where mobile devices widely overpass the penetration of PCs. In fact, in developing counties, mobile broadband penetration is continuously growing (reaching 21 per cent in 2014), while fixed broadband penetration rates are very low and dropping, from 18 per cent in 2011 to 6per cent in 2014 (ITU, 2014).

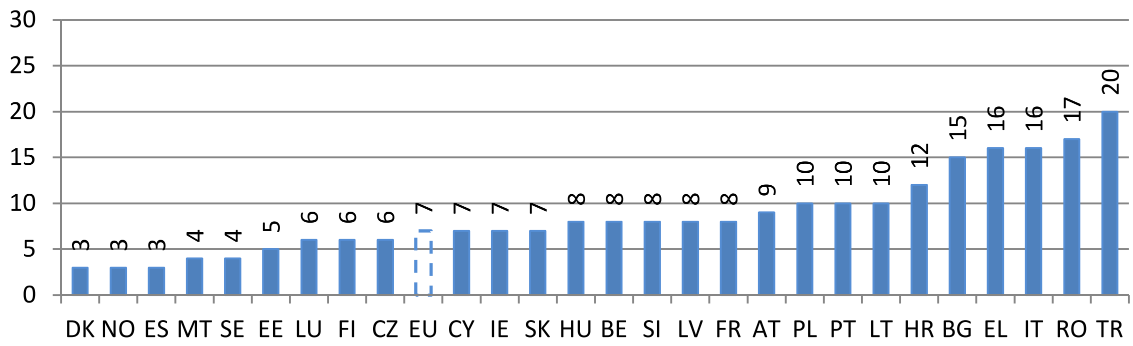
3.2.2. 1to1

1to1 (also called 1:1) refers to an educational programme that provides each student with one device, normally a laptop or a netbook, with which to access the Internet and educational content during the school year.

"One Laptop Per Child" (OLPC) programmes in primary and secondary education were launched around the world is the 1990s, particularly in the US. In Europe, these programmes were mainly developed during the 2000s in two waves: during 2003-2004, when the first laptop initiatives where launched aiming at spreading equipment at schools as part of ICT infrastructure programmes, and in 2007-2008, when the rise of 1to1 initiatives in Europe focused more on the promotion of the use of ICT, the acquisition of eSkills and the reduction of the first digital divide (S Bocconi, Kampylis, & Punie, 2013).

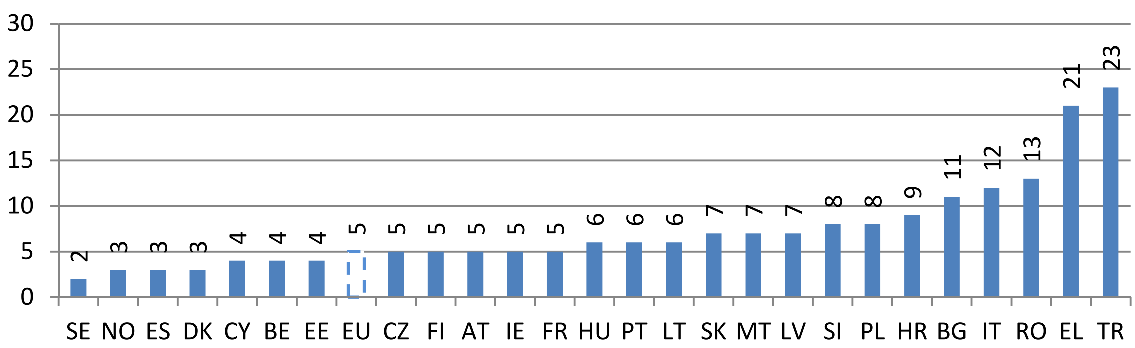
The following graphs show the extent of 1to1 computing in 31 countries in Europe (EU28, Iceland, Norway and Turkey) according to the Survey of Schools: ICT in Education 2013.

Figure 10: Students per computer (Grade 4, 2011-12)



Source: (E. Schoolnet & Liege, 2013)

Figure 11: Students per computer (Grade 8, 2011-12)



Source: (E. Schoolnet & Liege, 2013)

Some initiatives have been implemented widely across the education system (nationwide), such as in Spain and Portugal, while others have been smaller-scale pilots (regional or local) as in the UK, Italy or the Czech Republic (E. Schoolnet & Liege, 2013).

Many countries launched OLPC policies with the objective of closing the technology gap between social classes, reducing the digital divide and preparing children for the information society (Cuban, 2012). In addition to promoting e-inclusion and reducing the digital divide, these initiatives claim to increase student motivation and engagement (Argueta, Huff, Tingen, & Corn, 2011), enhance collaboration, improve students' eSkills and incorporate ICT across the curricula, better integrate formal an informal learning and support personalised learning (S Bocconi et al., 2013).

However, these programmes are very costly - not only due to the heavy initial investment in equipment and infrastructure, but also because of maintenance costs and technical support requirements; furthermore, the return on investment of these initiatives has attracted criticisms in recent years due to the lack of evidence of achievement gains (Hu, 2007).

Although some research shows that 1to1 programmes increase learning achievement, reduce students' absences and improve student discipline (Rosen & Beck-Hill, 2012), other studies criticise these initiatives for emphasising technology over pedagogical aims, and claim that technologies generate distractions (Jackson, 2009). Other concerns include security and privacy issues, and the increase of risks such as cyber-bulling when students take the devices home, where supervision is often lower than in the classroom (Securly, 2014).

Budget cuts and the penetration of cheaper technologies (tablets and smartphones) are shifting deployment models to new paradigms, such as BYOD as will be discussed in the following section.

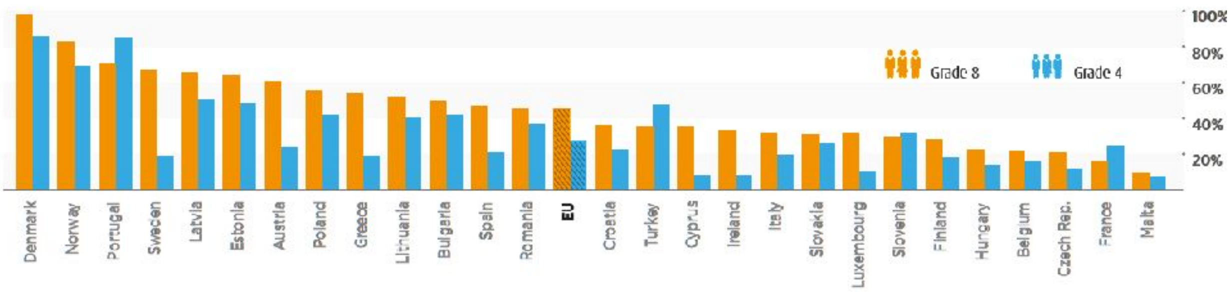
3.2.3. Bring your own device (BYOD)

Recent trends have shifted deployment models of technological devices from school-owned devices to an ownership model where students use their own device in the educational setting. In this model, devices are not provided by schools; rather they are brought into classrooms by the students to be used during lessons and educational activities.

This option has become increasingly accepted, as educational budgets shrink and access to smart devices by Europeans expand.[7]

Figures 12 and 13 show the extent to which BYOD practices have spread across the EU by indicating the percentage of students in grades 4, 8 and 11 that are permitted to use their laptop or tablet in class.

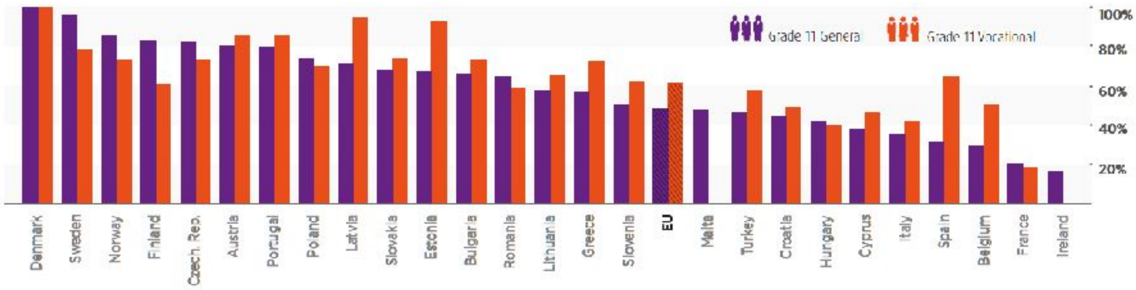
Figure 12: Percentage of grade 4 and 8 students allowed to use their own laptop/tablet in class for learning (2011-12)



Source: (Schoolnet, 2013)

[7] In December 2012, the EU5 countries (Spain, Germany, Italy, France and the UK) surpassed the 50 per cent smartphone penetration mark (Schindler, 2013).

Figure 13: Percentage of grade 11 students allowed to use their own laptop/tablet in class for learning (2011-12)



Source: (Schoolnet, 2013)

The BYOD principle has the same benefits as OLPC with the exception of reducing the first digital divide. The feasibility of BYOD depends on the availability of adequately advanced devices among students. All learners should have access to a suitable device. Theoretically, this approach is more sustainable, as schools are not responsible for providing devices to all students or ensuring the equipment remains updated.

However, equity issues arise with this model, since students who are unable to access a device could be stigmatised. To avoid equity issues in these models, policies and programmes normally include the possibility of providing grants to families or enabling students to borrow the required devices from schools.

Other concerns include problems managing and securing devices and data, and problems with the interoperability and standardisation of systems, platforms and contents.

3.2.4. Self-driven or self-regulated learning

Self-driven learning refers to learners self-managing the process towards their educational goal: the acquisitions of skills and knowledge (Zumbrunn, Tadlock, & Roberts, 2011). Also called self-regulated learning, it emphasises the need for autonomy and responsibility, factors considered critical to any learning process, thus improving academic achievement (Zumbrunn et al., 2011).

Being in charge of one's own learning is not a new concept and is not necessarily linked to ICT. However, ICT provide tools to increase the control of learners over their learning process and outcomes, making it easier for learners to self-direct their education. ICT can help students to plan, monitor and assess the way they learn, which can lead to improving their motivation and perseverance.

Self-driven learning is closely linked to learning and teaching practices, such as flipped learning and personalised learning or self-assessment, since these practices require high levels of autonomy and self management in order to be successful.

Self-driven learning is particularly relevant for the design and implementation of lifelong learning strategies.

3.2.5. Personalised learning and assessment

Learners are different and learn in different ways. Differences are not only socio-demographic (sex, social sphere, race, etc.) but also include educational and cultural differences. There are diverse ways of learning: some students are visual learners, some auditory learners, some are faster learners and some slower.

Personalised learning and assessment aims at providing students with an educational strategy that matches their individual needs.

Since personalised learning consists of the provision of tailored contents and teaching tactics, enabling technologies and tools are essential both in the definition or design process (analysis of the student's context and needs) and in the implementation process (contents itself and tools for delivering contents). As for assessment, ICT offer the chance of providing personalised feedback on student's performance at any stage of the learning process and therefore guiding them in a more flexible and individualised way. Infrequent - once or twice a year - standardised tests are not suitable for personalised learning environments since they do not allow establishing causal relations of test results (West, 2011). Tools such as real time computerised assessment, automated scoring, specialised apps, or even twitter discussions, can be used to personalise assessment to learners' needs. These assessments can complement traditional assessment methodologies.

To personalise learning and assessment, teaching tools need to capture how learners perceive and process information, and understand how they learn. To do so, data that characterise users needs to be collected; data on applications and users interactions with the applications is also required (Butoianu, Vidal, Verbert, Duval, & Broisin, 2010). This raises concerns regarding the privacy of student's information. Tools and techniques for personalising education include data mining and decision trees (L. Johnson et al., 2014).

On the other hand, tools and services that deliver education content can also be personalised to the requirements of learners; social media and cloud computing tools being particularly useful.

3.2.6. Peer-to-peer assessment

Peer assessment is an active learning approach that highlights the benefits of peer-provided feedback to students. It consists of the assessment of a learner's work by other learners. This practice requires students to engage in collaborative activities with their peers, which is now becoming easy thanks to IT collaborative tools and services.

By providing and receiving feedback to/from peers, students develop the abilities required to assess others' and their own work; they also develop critical thinking and interpersonal skills and improve their self-awareness. This process requires the development of an evaluation criteria. This approach can also promote discussions among students and allows students to analyse peers' views and perspectives; this process becomes an assessment as well as a learning technique for students. Peer to peer assessment can be anonymous or public. It is normally preceded by a training session or a self-evaluation; generally, assignments are evaluated either collectively by the class or by more than one peer. It can be used for individual assignments or to evaluate the contribution of one student working as part of a group (Committee, 2010). This practice helps to reduce lecturers' workload and is becoming a widespread practice in MOOCs. Although this assessment does not necessarily require the use of ICT, peer-to-peer assessments in environments such as MOOCS would not be possible without these technologies. In other educational contexts, ICT also facilitate its implementation thanks to collaborative and communication tools and allows anonymity; ICT also make it possible for people from other locations to partake in the assessments.

3.2.7. Flipped learning

This pedagogical model rearranges how educational time is used, moving certain learning processes or activities (such as lectures or information) out of the classroom; it also uses class-time to facilitate other processes and practices, such as group work, discussions or interactive activities (L. Johnson et al., 2014; Larry Johnson et al., 2014a; Johnson, Adams, Estrada, & Freeman, 2014b; Panzavolta & Carvalho, 2013).

In this model, what was once homework is brought into the classroom, where teachers can interact with students, engage in valuable discussions, solve questions or make exercises or demonstrations of real-world applications of the subjects.

At home, students can obtain information through online lectures (online content, videos, podcasts) and collaborative online work. Flipped learning enhances the role of the teacher as a guide.

Emerging technologies allow teachers to take lectures out of the classroom and encourage students to take control of their learning process. Teachers can use the valuable class-time to provide more personalised teaching and coaching, and students can access educational content and information as many times as needed to process lessons.

3.2.8. Game-based learning and gamification

Gamification refers to "the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals" (Gartner, 2014b). Game-based learning is the learning process that takes place though the use of digital or video games. This concept includes the use of the so-called "serious games" - games used for non-entertainment purposes.

The impact of games on human behaviour has long been studied (McFarlane, Sparrowhawk, & Heald, 2002; Passey et al., 2004; Sandford, Ulicsak, Facer, & Rudd, 2006). Although the direct impact of games on educational performance is still controversial, there is general consensus on the motivating power of games and their benefits on attitudes towards learning. Games have the potential to engage students in repetitive tasks, helping them to acquire new skills (L. Johnson et al., 2014), including social and cognitive skills. Existing research (Gee, 2003) argues that certain features of gamers are particularly valuable in today's digital era, such as problem solving and communication skills, persistence, risk taking, and detail orientation, and for that reason games can foster learning. One of the most important attributes of games in education is the fact that players feel free to fail during the game, because the cost of failing is low (or inexistent) compared to a real-life context, encouraging players to risk and experiment (Klopfer, Osterweil, & Salen, 2009).

Game based-learning seems to be particularly effective in elementary and primary education, because of its impact on the cognitive development of children (Miller & Robertson, 2011).

Khan Academy is an example of the gamification of education. It does not consist of a game but applies gaming mechanics into its teaching practice, for example, through using rewards and badges (www.khanacademy.org).

On the other hand, **SmartKid** is an example of game-based learning. This Finnish game aims at teaching maths to children 4 – 8 years old through games. The app is available for mobile devices and includes personalization features thanks to learning analytics (www.skillpixels.com).

Gamification of education involves using games (the so-called serious games) as a teaching tool; it can also involve applying game techniques in teaching and learning practices, that is, creating "gamelike" environments.

These environments, to be considered "gamelike", need to include the same features as games, that is: they need to be "a rule-based formal system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels attached to the outcome, and the consequences of the activity are optional and negotiable" (Juul, 2003, p. 5). In this sense, the existence of a reward system and a challenging situation are essential features of these environments.

Learning by playing can be integrated into the classroom in different ways. The following has been suggested by Klopfer et al. (2009):

- Games as technology gateways: games are tools to familiarise learners with certain technologies (hardware, software or platforms).
- Games as illustration: games generate a context that encourages students to reflect.
- Games as exemplars of point of view: by taking on different identities, students can analyse scenarios from various points of view and compare strategies, behaviours and choices.
- Games as research systems: gamers design games on a topic, which requires them to research that topic.
- Games as trigger systems: games are the base for a further discussion on issues introduced in the game.
- Games as authoring systems: games are used as platforms for creation: text, models, visual objects, etc.
- Games as content: students learn from the content of the game itself, such as playing "Civilization" to learn about history.
- Simulations: games are used to test theories and tinker with variables of systems.
- Games as code systems: by writing code (for a game) students understand and learn programming.
- Documentary: games are tools to document student's learning process.
- Games as ideological systems: games are tools for "reading", enabling students to criticise the ideology or context behind them. Games are a base for discussion.
- Game as assessment: games are tools for assessing students.

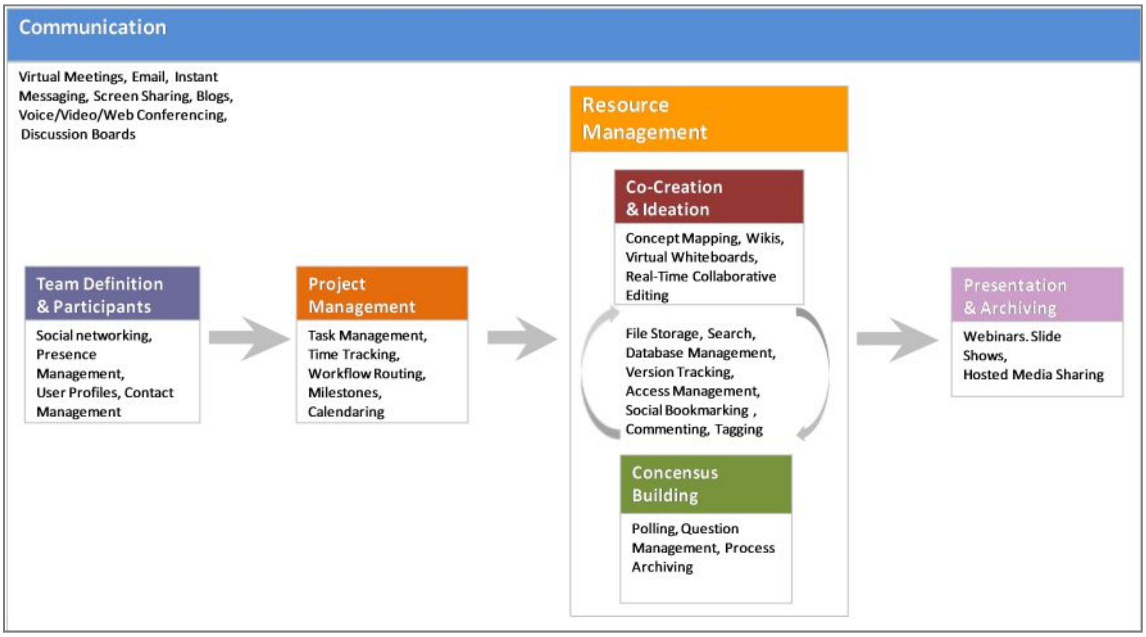
3.2.9. Collaborative learning and collaborative creation

Collaborative learning refers to the process of learning where students and teachers engage in a common task towards a common goal, taking advantages of each others' skills and knowledge. Collaborative learning has been commonly used in education, for example through group assignments or class debates.

However, technologies have introduced new communication tools and have expanded the possibilities of collaboration in the teaching and learning processes. Collaboration can now be part of any element of the teaching and learning process: including the design process, implementation, presentation and assessment.

One common methodology of collaborative learning is the project-based collaborative learning approach, a combination of project-based learning and collaborative learning (Deal, 2009). The following figure shows the different element of the process and describes technologies that can support each process.

Figure 14: Technologies for project-based collaborative learning



Source: (Deal, 2009)

There is also a trend towards teachers across the world working together in the creation of resources and services, and students actively participating in the process. Existing technologies allow for the ubiquitous co-creation of contents and resources in real-time.

This practice or approach to education is linked to the development of OER and faces limitations due to intellectual property restrictions, especially with regards to cross-border practices.

Crowd-learning

It refers to the learning process to which a large group of people contribute their knowledge and expertise. It entails applying the trend of crowdsourcing to the world of education. (Surowiecki, 2004).

Crowd-learning blurs the lines between learners and teachers; it also allows students to obtain information on any issues at any time, as technologies enable anyone to participate in a discussion or to provide information from any place in the world (Sharples et al., 2013). Students have already taken this immediacy of information for granted.

Skillshares, a US platform launched in 2011 "is a learning community for creators. Anyone can take online classes, watch video lessons, create projects, and even teach a class themselves" (Skillshare, 2015).

Tiching is another example of a crowd-learning platform. It has over 500,000 users including teachers, students and families. Also launched in 2011, it is the largest learning community in Spain and Latin America (Tiching, 2015).

3.2.10. Massive Open Online Courses

Massive Open Online Courses (MOOCs) are online courses characterised by two main features: courses are mostly free and imparted through technological platforms, which enable concurrent access from thousands of users.

The course, *Connectivism and Connected Knowledge* (CCK08), imparted in 2008 by Stephen Downes and George Siemens from Manitoba University in Canada, marked the start of the MOOC concept. Additionally, the MOOC concept is inscribed in the field of open models, specifically under the Open

Course Ware (OCW) paradigm. The Massachusetts Institute of Technology (MIT) launched its OpenCourseWare (MIT, 2014) in 2001, marking the beginning of a new general trend of educational content becoming available through the Internet. Since 2008, the term MOOC has been used to refer to courses which bare resemblance to the CCK08 (open creation tools available to a large number of participants, free access and active student participation); the courses attempt to materialise the paradigm of the Open Course Ware (OWC)

The new teaching model (EDUCAUSE, 2013) is based on the following premises:

- The courses have a course structure, with objectives and milestones within a series of learning areas.
- They are available online, as they are developed in virtual environments and allow connections from remote places through the Internet.
- They have a massive outreach: the technological platforms through which they are imparted allow access to a large number of students.
- Their content is open: they offer access to both content and participation to all. When it comes to property and types of license of the content for its reuse, no homogenous criteria exist as it varies for each platform.

Over the past few years, there has been an important increase in the number of MOOCs in Europe, although the largest concentration of courses is still the US, where the three main providers are located (Coursera, edX and Udacity) (Gaebel, 2013). At the end of 2013, the European Commission started a MOOC Scoreboard (EC, 2014b) which enabled comparisons to be made between countries. This portal offers updated information about MOOC evolution in European countries:

Figure 15: Number of MOOCs in Europe per country of origin

Source: European MOOCs Scoreboard (data retrieved: November 2014)

MOOCs are closely linked to two relevant trends in education: personalisation of education and learning analytics.

MOOCs, born out of the OCW philosophy, offer very high personalisation levels. This personalisation is oriented towards the two main convergent agents in the platforms: educational entities, which develop the courses, and the students. From perspective of the service provider, educational entities design and develop the courses offering multiple personalisation options from an educational point of view. The creators of the courses have the capacity to choose the format of the classes, the degree of interactivity with students, evaluation criteria and the tools to carry these out. In this regard, there are different platforms in the market which facilitate tailored development of MOOCs, such as Wemooc or Coursites. From the demand side, MOOC users have numerous personalisation tools, such as notifications, hand-in reminders, etc., improving user experience.

The application of learning analytics techniques allows MOOCs to understand student preferences and performance in detail based on their activity in the platform, suggesting new courses which may be potentially attractive to students, while simultaneously incrementing platform retentions. The type of personalised education which the MOOCs provide represents a great opportunity for them to become an alternative to traditional education.

Overall, MOOCs are an opportunity to experiment in many areas, for example, with regards to curriculum innovation or creating new assessment methods. MOOCs are a laboratory for innovation, particularly for testing emerging technologies like artificial intelligence tutors, automatic assessments tools or the aforementioned field of learning analytics (Sharples et al., 2013).

Student evaluation and qualifications

Course evaluation is one of the challenges confronting MOOCs, both from a technological and educational perspective. Assessment methods vary considerably based on the subjects. The course teacher is responsible of designing them, according to the technological possibilities offered by MOOC platforms. There are three general assessment and evaluation tools: short multiple-choice tests, peer-assessment evaluation, in which students enrolled in the course correct each other's projects and automated assessment tools. Essays can also be corrected by teachers; however this is less frequent due to the volume of student submissions. Finally, there are also automated content evaluation systems, which detect student's levels of participation and involvement in forums and other various platforms.

Obtaining qualifications after completing a MOOC is one of the main motivators compelling students to enrol and complete the courses. Furthermore, granting certificates or validations for the courses by means of university credits are some of the diverse business models, which are being explored in order to for the MOOC platforms to be financially viable. Aside from the mere achievement of emblems, many of the MOOC participants look for some kind of specific recognition after course completion. The lack of official recognition from the educational entity that imparts the courses signifies an important barrier in the consolidation of these models.

Open debates

Debates around MOOCs are focused on numerous issues, such as their financial viability, their "elitist" character due to the current user profiles (young individuals with graduate studies) and the low completion rates (approximately 10 per cent of students complete the programmes; therefore, for average enrolment of 20,000 students, only 2,000 students are completing the course) (Jordan, 2015). Language issues might also be a barrier for its development, particularly in Europe. Based on courses included in the European MOOC Scoreboard (EC, 2014b), around 48 per cent are in English, 27 per cent in Spanish and 15 per cent in French.

Finally, there is also controversy surrounding the quality of the interactions generated between MOOC participants. As the interactions take place in a virtual environment as oppose to customary interactions in traditional classrooms, they are considered to be less personal and profound.

3.2.11. Seamless learning

Although seamless learning is defined in different ways by various academics, all the definitions include the idea of supporting fluid learning, that is, blurring the lines between different learning environments and settings (Looi et al., 2010).

Achieving a continuous and fluid learning experience is possible nowadays thanks to emerging technologies, especially mobile technologies (mLearning) and ubiquitous computing (Milrad et al., 2013). However, seamless education does not only refer to the possibility of studying anywhere and anytime, but also to the smooth transition between formal and informal contexts, across devices (mobile or not), tasks and assignments or teaching and learning approaches.

Looi et al. (2010) define ten characteristics of mobile seamless learning (MSL):

1. Encompassing formal and informal learning;
2. Encompassing personalised and social learning;
3. Across time;
4. Across locations;
5. Ubiquitous access to learning resources (online data and information, teacher-created materials, student artefacts, student online interactions, etc.);
6. Encompassing physical and digital worlds;
7. Combined use of multiple device types (including stable technologies, such as desktop computers and interactive whiteboards);
8. Seamless switching between multiple learning tasks (such as data collection, analysis and communication);
9. Knowledge synthesis (a combination of prior and new knowledge, multiple levels of thinking and multi-disciplinary learning);
10. Encompassing multiple pedagogical or learning activity models.

The seamless learning approach challenges the traditional vision of education. Learning takes place in different spaces (not only in the classroom or the workplace), at different times (not only during specified times designated for lectures), and encompasses not only knowledge and notions, but also important skills such as social skills, creativity, initiative, collaboration and informed decision-making (Milrad et al., 2013).

To implement seamless learning, learning environments must expand across the learners' contexts. This can be achieved through one learning management system covering all the student's needs or by facilitating the use of the student's own devices and tools throughout the educational process. The second option requires resources to be synchronised and systems to be interoperable.

3.2.12. Learning analytics

Educational institutions are accumulating a significant amount of data. As in many other areas of our digital lives, data is increasingly being used by institutions, private or public, to obtain valuable information with multiple goals: national security, scientific research, commercial aims, etc. The application of data analytics to education may bring many benefits, including innovation in assessment methodologies and teaching practices, such as in areas of personalising learning and the design of new curricula (Broadfoot, Timmis, Payton, Oldfield, & Sutherland, 2012).

Data most commonly used for learning analytics by educational institutions include both information directly provided by the student (personal information about the student and contact details or data regarding the student's record and performance) and data gathered indirectly from the activity of the student and his/her interaction with the educational institutions and its services (data generated from the use of services, such as the library or virtual learning environments, or interactive content generated by the student) (JISC, 2014).

However, these techniques raise serious privacy and ethical concerns, particularly when minors are involved.

3.2.13. Summary of practices

The following table summarises the main elements of the practices and methodologies analysed. The practices have been matched according to the educational level to which they are most commonly applied.

Table 1: Summary of learning and teaching practices

Practice	Educational level	Related technologies	Stakeholders involved	Linked practices/ methodologies	Regulatory/organisational implications
mLearning	Secondary education and lifelong learning	Requires mobile broadband connectivity Mobile devices Cloud technologies Virtual Assistants	Students Teachers Families Policy makers, officials	BYOD Seamless learning Personalised learning Self-driven learning	Security and privacy issues Standardisation and interoperability
1to1	Primary and secondary education (K12)	Requires robust network infrastructure at schools One device per student: laptops, netbooks, tablets OERs	Students Teachers Families Policy makers, officials	BYOD Personalised learning Self-driven learning	Security and privacy issues Requires technical support at schools and maintenance Cyber security concerns
BYOD	Secondary education	Requires robust network infrastructure at schools Wireless Internet connection Devices Digital whiteboards Cloud technologies OERs	Students Teachers Families Policy makers, officials	1to1 Personalised learning	Security and privacy issues Cyber security concerns Equity issues Standardisation and interoperability
Self-driven learning	Secondary education, higher education and lifelong learning	Personal devices Cloud technologies Virtual assistants Learning platforms	Students Teachers	Personalised learning and assessment Flipped learning	
Personalised learning and assessment	All levels of education	Learning management systems Data mining tools Content delivery tools and services Artificial intelligence / self-learning software	Students Teachers Officials	Self-driven learning Collaborative learning	Security and privacy issues New assessment methodologies need to be validated/recognized

Peer-to-peer assessment	Mainly used in higher education and lifelong learning. Commonly used in MOOCS .	Requires infrastructure at home or in the classroom (Internet and a device at home) Collaborative tools Self- assessment tools	Teachers Students Principals/ officials	Self-driven learning	New assessment methodologies need to be validated/recognized
Flipped learning	Primary and secondary education (K12) and higher education	Requires infrastructure at home (Internet and a device) Content is crucial: videos, podcasts, interactive materials, etc. Social media and collaborative tools	Students Teachers Families	Deeper learning Self-driven learning OERs	Standardisation and interoperability
Game-based learning and gamification	Primary and secondary education	Consoles and other video games infrastructure (3D glasses, motion devices, etc.). Compatible devices (PCs or laptops with sufficient capacity for modern video games) Integrated learning systems (ILS)	Students Teachers	Seamless learning	Skills enhanced by games are not assessed by standard assessment systems High costs regarding the development of adequate games and updating contents
Collaborative learning and collaborative creation	All educational levels	Cloud technologies Digital whiteboards Personal devices Social media Web communication and collaborative tools OERs	Teachers Students	Cooperative learning	Intellectual property protection Cross-border management of intellectual property rights (IPRs) Privacy Language barriers
MOOCs	Higher education and lifelong learning	Learning management systems Technological MOOCs platforms Mobile devices Virtual assistants Learning platforms	Teachers Students Managers / officials	Personalised learning Learning analytics Collaborative learning Peer assessment mLearning	Recognition of certifications Management changes of higher education institutions Language barriers Equity issues
Seamless learning	Lifelong learning and all educational levels	Mobile devices Wearable devices Social networks Learning platforms	Students Teachers Families Policy makers, officials	BYOD mLearning Collaborative learning Personalised learning	Standardisation and interoperability
Learning Analytics	Lifelong learning and all educational levels	Data mining tools Learning management systems Artificial intelligence / self-learning software	Students Teachers Families Policy makers, officials	Personalised learning	Security and privacy issues

4. THE ROLE OF THE STAKEHOLDERS

The main stakeholders in the education system are teachers and students. However, there are other stakeholders that play a relevant role and must be taken into account: politicians and public officials, managers (principals at school level and chancellors at university level), families, communities, and the industry. These stakeholders are closely intertwined and are constantly interacting among themselves (students and families, families and teachers, teachers and principals), and the success of the education process depends on the attitude of the individuals within the group and on the interactions between the individuals of other groups. All stakeholders play a pivotal role in guaranteeing that technology is adequately integrated into the educational system; therefore, it is important to understand the evolving role of stakeholders through technology and the strengths, weaknesses, challenges and barriers facing the different groups that are fostered by the digital environment.

4.1. Policy-makers

Politicians and public officials are in charge of enacting and developing the policies that will support learning in the digital context by guaranteeing that schools and universities are technologically equipped, and that teachers and students have the required skills that will allow them to draw upon the benefits of new contents, services, and methodologies while preserving equality. Without the right policies it is impossible for students and teachers to achieve the proficiency required in the new connected environment. Policymakers' leadership provides the strategic vision to align the efforts of the different stakeholders, while legitimating the process. The regulatory environment can foster or hinder the development of innovative tools and services. In enacting new legislation, policymakers should be very cautious about unexpected impacts on the technology ecosystem; it is important to strike the right balance between potential benefits (such as guarantying privacy and property rights or protecting European industries) and concealed risks (such as hindering the development of innovative business models or the adoption of market standards). Policymakers should also find a balance between guiding educational leaders and leaving a margin of autonomy to education bodies in order to ensure that policies are adapted to the specificities of the local contexts. In fact, higher levels of autonomy at the institution level are likely to yield better results but only if the results are externally evaluated (Escardibul & Calero, 2013).

Ultimately, policymakers should strike a balance between promoting a real shift through innovative policies and considering the current interests of stakeholders who would otherwise be opposed to adopting the policies.

4.2. Education leaders (principals and chancellors)

Education leaders act as important catalysts for change; they foster an environment where technology is pervasive and smoothly integrated into the educational process by being leaders of new ways of learning in the Digital Age. A systematic focus at the organization level is the key to success. The first step for educational leaders is to assess the readiness of their organization to embrace the digital change and to adapt their organizations to the new requirements of the connected society. If principals are effective users of technology and show positive attitudes towards technology use, they will likely initiate and support learning initiatives by allocating funds for technology use within the school (Brown, 2010) and by rewarding teachers using innovative approaches (EC, 2013c, p. 4; E. Schoolnet & Liege, 2013, p. 12). Education leaders are the main people responsible for evolving and improving the learning environment at the school and university level by providing strategic visions, defining consistent priorities, establishing clear goals, creating a supportive environment, and developing actions aimed at transforming closed institutions into connected, open learning communities. For instance, ICT are used more often at schools that incentivise teachers through rewards and professional development, whereas holistic ICT policies exist at the general and subject level (E. Schoolnet & Liege, 2013, p. 12).

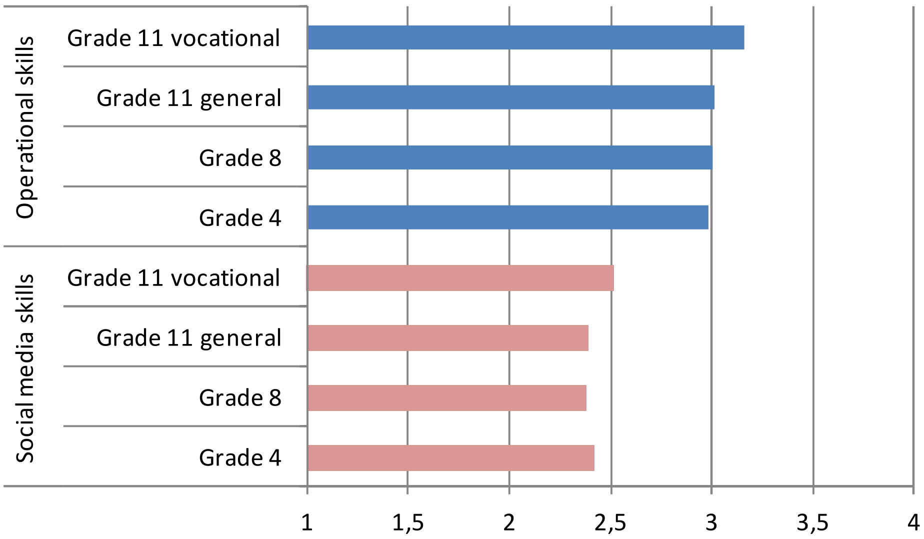
4.3. Teachers

Teachers play a pivotal role in integrating technology into education. Technology is fostering new ways of teaching and learning where students have access to multiple learning resources and the teacher becomes a facilitator (chapter 3.2.7), and where students become active participants of the teaching process by developing collaboratively educational contents (chapter 3.2.9) and assessing their peers (chapter 3.2.6). Understanding how teachers can properly use technology in education is an essential part of improving the technology integration process. The effect of using technology in the education environment depends on several teacher-related factors, however, the ability of teachers to use and integrate technology is the most relevant. Numerous literature surveys link student technological achievements to teachers' opportunities to develop their own computer skills (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). Teachers who have not been trained in the use of technology or do not understand how to integrate it into the education environment are unlikely to even make an attempt to do so. Even after holding basic technology skills, teachers face additional challenges fostered by new teaching trends such as: the active role of teachers in using, developing and sharing contents, the shifting role of students towards more active participation models, the incursion of more sophisticated and ubiquitous devices with advanced capabilities, the increasing knowledge of students personal specificities, and the role of social media in the educational process. Therefore, training programs are essential for teachers to be able to keep up with these constant improvements and changes in order to teach their students by drawing upon the new trends and technologies available (Booth, 2008).

However, not only skills, but teachers’ attitudes, abilities and experience have also been found to be relevant factors affecting the manner in which technology is used (Pierson, 2001). In fact, the most important factors in determining whether teachers are adequately equipped to successfully use and teach technology are content knowledge and pedagogic skills; however, the majority of teachers around the world have not been sufficiently equipped to meet the changing educational needs of modern society, and many teachers seriously lack pedagogic skills regarding supporting individual differences in students (Gumbo, Makgato, & Müller, 2012). Studies have shown that the mere use of computers has little effect on student achievement; teachers need to be properly trained not only in technology, but in using technology in the classroom while taking into account the specific characteristics of the students, in order for technology use to have an impact (Booth, 2008; Gumbo et al., 2012; Stone, 2010).

However, a lack of ICT education among European teachers is seen as one of the most relevant factors hindering a deeper integration of technology in education (L. Johnson et al., 2014, p. 22). Teachers use the technology to prepare their classes rather than to foster new ways of learning and teaching (E. Schoolnet & Liege, 2013, p. 3); furthermore, less than 25 per cent of students are taught by digitally confident and supportive teachers (EC, 2013c, p. 2). In fact, teachers’ confidence in their technology skills is intermediate as can be seen in Figure 16. Teachers are even less confident in using social media, showing a stark contrast to the social media abilities of the students.

Figure 16: Teachers' confidence in their operational and social media skills

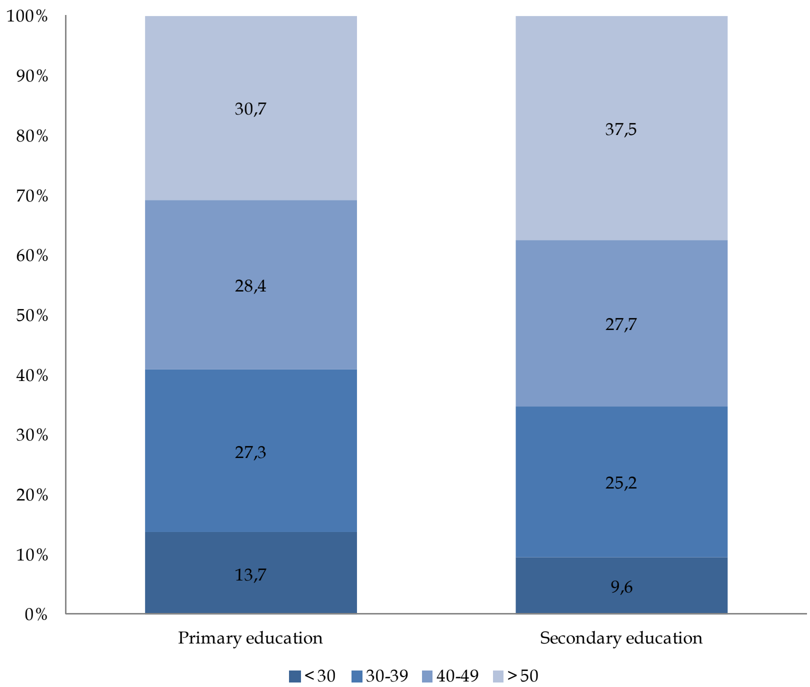


Source: (E. Schoolnet & Liege, 2013, p. 81)

Note: Mean of teachers' confidence weighted by number of students in EU27 in 2011-12. Scale: 1 (none) to 4 (a lot)

One of the reasons for this could be the age of teachers in Europe. In 2013, more than 60 per cent of teachers in EU27 were over the age of 40 (see Figure 17); therefore, they were educated at a time when ICT were significantly less pervasive.

Figure 17: Distribution of teachers by age group in EU27 in 2010



Source: (Eurydice, 2013b, p. 91)

4.4. Students

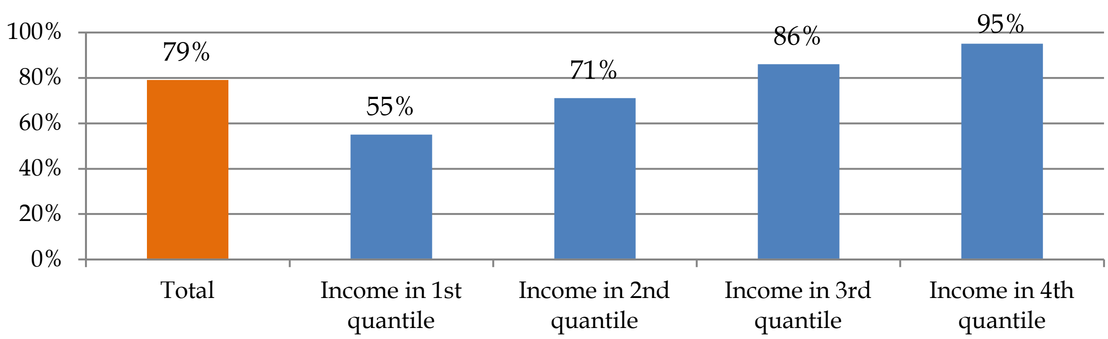
Students are the central element of the educational process. While students were considered passive recipients of knowledge in traditional educational models, their role is becoming increasingly active in the new digital environment. Students are expected to develop and share information and contents, give their opinions, interact with other students and teachers, and even assess the results of their peers. However, there are two factors hindering this process. Although students, particularly youth, use technology on a daily basis, their digital competences are inadequate when it comes to undertaking participatory and critical computer tasks, such as developing media contents, programming or analysing data (L. Johnson et al., 2014, p. 26). Although students are considered digital natives, only 30 per cent of European students can be considered digitally competent (EC, 2013c, p. 6). Further, school leaders and teachers are unable to figure out how to shift more control to students in the learning process (L. Johnson et al., 2014, p. 23). As a result, between 50 per cent and 80 per cent of students in Europe never use digital materials — digital textbooks, software, simulations, or learning games (EC, 2013c, p. 2).

4.5. Families

The role of the families is considered to be one of the most important factors when analysing the effect of technology on educational achievements. Income and parental education are closely related to children's achievement (Reardon, 2011). Household socio-economic status is also the strongest factor related to the digital exclusion of low-income children. In fact, Internet penetration among European households is strongly related to family income as can be seen in Figure 18. Moreover, there is evidence that Internet use is more sophisticated among students in affluent areas in comparison to other urban and rural areas (Wood & Howley, 2011). Therefore, family income and parental education are strongly related to digital and achievement gaps, and this relationship is expected to grow in the absence of further effective measures.

Families are responsible for providing a home environment that supports digital learning. Although some studies (Tondeur, Sinnaeve, van Houtte, & van Braak, 2011) suggest that socio-economic status only moderately affects the digital profile of young people, a lack of computers and Internet connectivity at home is likely to leave students of low-income families behind.

Figure 18: Internet penetration by household income in EU28



Source: Compiled by the authors based on (Eurostat, 2014d)

Technology benefits affluent students more than poor ones (Krumsvik, 2008), thus contributing to increasing socio-economic inequalities (Mason & Dodds, 2005). There are several consequences for students: (1) poor academic achievements (Castaño-Muñoz, 2010; Huang, 2006; Judge, Puckett, & Bell, 2006; Wainer et al., 2008) and learning outcomes (K.-K. Wei, Teo, Chan, & Tan, 2011); (2) low interest in socio-political activities (Sylvester & McGlynn, 2010) and on making life plans (Goode, 2010); (3) lack of digital skills (van Deursen & van Dijk, 2011) - particularly to properly use the Internet (Meyen, Pfaff-Rüdiger, Dudenhöffer, & Huss, 2010) including the type and the number of Internet services used (L. Wei, 2012) - to draw upon today's abundance of digital resources (Horrigan, 2011), and to properly use computers (K.-K. Wei et al., 2011).

However, having equipment at home is inadequate. The successful role of families is challenged by the digital skills of parents and their involvement in the education process. The randomised experiment carried out by Fairlie and Robinson (2013) shows that having computers at home is very unlikely to achieve the goal of improving educational attainment by itself. An absence of parent involvement in poorer and minority households can contribute to the computers having no effect (Malamud & Pop-Eleches, 2011) or even having a negative effect (Vigdor & Ladd, 2010) on the academic achievement of children. A broader program including family training could lead to better results.

4.6. Community

Community refers to citizens and companies not directly related to the educational system but willing to provide knowledge, funding, and services to improve the integration of technology in education, and to NGOs cooperating with schools, governments and companies in topics related to educational technology.

NGOs can act as venues to bring other stakeholders together. For instance, schools and governments can be reluctant to cooperate with companies, and therefore companies can more easily reach schools working through NGOs. Individual citizens may be interested in providing their technology skills and knowledge to help schools to integrate technology into the educational process or to raise awareness among parents regarding the benefits of using technology at home; however, it may be difficult for these individuals to reach schools. Consequently, this is a role that NGOs can fill.

The main ways in which the community can support educational technology are: providing specific infrastructure, contents, applications and services, raising awareness as well as training the different stakeholders (teachers, families, and students).

4.7. Businesses and industry

The main business sectors affected by the introduction of ICT in education are technology providers (connectivity, hardware and software) and educational service providers (both traditional publishers and new eContent and application providers).

For the ICT sector, in a wide sense, the integration of ICT in education is an obvious opportunity. Within this sector, we can include three main types of providers: (1) technological infrastructure providers (software, hardware and connectivity) at the central data centres, schools, and homes; (2) support and maintenance service providers to guarantee that the different systems work properly; and (3) digital educational contents, applications and digital services providers (e-learning platforms, distribution platforms, school management system, family engagement software, etc.). There is also the sector of eLearning companies providing comprehensive portfolios of eLearning solutions mainly focused on the business sector.

Technology infrastructure is usually provided by established ICT companies while e-learning products and services are provided by emerging companies in the Internet arena. Europe has traditionally maintained a leadership position in the telecommunications equipment segment and in the *handsets* and telecommunications services (connectivity). This leadership has given the telecommunications sector a much higher relevance inside the ICT sector in Europe, while other areas related to the Internet, contents and media companies have developed less; however, in the United States, these companies have greater influence.

For example, a basic analysis of the companies included in the *Fortune Global 500*[8] (Fortune, 2015) shows how European Union potential, within this sector, is located in the telecommunications and telecom equipment sectors. Therefore, Europe is missing the opportunity to lead the development of valued added e-learning products and services. Conversely, the US is more specialised in *software, hardware* and *media*, while in the rest of the world, *hardware* and *electronics* are the main sectors, especially for Asian companies. Nowadays, even in terms of maintaining a certain leading position, European industries are increasingly threatened by innovative US providers on the one hand, and the inrush of manufacturers, mainly Asian, on the other. In fact, the European position has significantly weakened over the last years (WTO, 2014).

This characterisation of the European ICT industry results in a particularly weak position of European companies in the education technologies sector. The sector in Europe is characterised by strong fragmentation, small-sized companies and low levels of investment (Vedrenne-Cloquet, 2014). Kompass International found around 3,000 European companies in the e-learning sector (IBISCapital, 2013, p. 23). A consolidation process is taking place in the industry. Since 2007, strategic buyers have acquired 67 per cent of total targets but the US dominates the process by the total number of deals and value (IBISCapital, 2013, p. 26). The US is also the most active in terms of global fundraising, accounting for 58 per cent of deals in e-learning. India and China are also important players accounting for 12 per cent and 9 per cent of total deals, respectively. Europe is lagging behind, accounting for 6 per cent of total fundraising volume (IBISCapital, 2013, p. 27). In summary, Europe's presence in the emerging e-learning market is relatively minor, on account of fragmentation of the market, low levels of fundraising, and with few European key players having an active role in consolidating the market in comparison to the US.

Pearson, the world's leading publishing company, is investing heavily in acquisitions (2.5 billion pounds since 2006). It has acquired 11 companies since 2010; they are all related to digital businesses including content, LMS, and analytics companies, such as LearningStudio, a Cloud-based LMS and OpenClass, a social learning environment. Pearson also runs strategic alliances with technological companies such as Cisco Systems and IBM (Docebo, 2014, p. 41). In 2011, 33 per cent of the company's revenue was derived from digital business compared to 20 per cent in 2006 (IBISCapital, 2013, pp. 59-60).

The emergence of successful sub-sectors, such as mobile education, educational apps or educational games, represents an important opportunity for European industries; however, this opportunity has yet to be adequately explored. AmbientInsight (2013) predict an annual growth rate of 18.2 per cent for the mobile learning worldwide market between 2012 and 2017; they also anticipate that subscription-based mobile learning service revenues will quadruple during the same period.

A business sector that deserves special attention is the traditional publishing sector. European publishers have traditionally held a world leading position. However, during the transition to the digital era, European companies have lost their dominant position in favour of US technological companies. The current e-book sector is dominated by online distributors such as Amazon, Google and Apple (Feijoo et al., 2013). The proliferation of open educational contents worldwide is also challenging their traditional business model.

As a result, publishers need to move from traditional textbooks to the provision of new innovative services and tools. Some big players, such as Pearson, are moving into the digital arena through a

[8] Fortune Global 500 is a list of the 500 largest corporations worldwide ranked by revenues.

strategy of acquisitions. Other players, such as the Spanish Association of Publishers, are creating platforms where publishers can deliver high quality contents to the educational community. However, it is expected than the resultant market will be will be smaller than prior to digitisation, forcing traditional publishers to substantially change their structure and to find new business models. To compound the problem, it is likely that the evolution of the market will be driven by new innovative players making it more challenging for publishers to keep up the pace (Feijoo et al., 2013, p. 13).

5. THE FUTURE OF EDUCATION IN EUROPE

High and stalled unemployment rates and increased competition from Asian countries are turning the productivity of workers into a strategic policy issue in the EU. Governments are increasingly fostering active public policies to improve productivity through the acquisition of new skills, while the use of Information and Communication Technologies (ICT) is expected to be one of the most crucial abilities in the knowledge society.

The theory of human capital states that workers obtain education to favour the accumulation of competencies to increase wage earnings and to improve the chance of being employed (Cahuc & Zylberberg, 2004, p. 91). ICT competences play a twofold role: they act as a means to facilitate the acquisition of new attitudes, knowledge and skills, and they are also considered to be stand alone competencies, both in general and more specific terms. In fact, the e-skills of the workforce are considered as a crucial element for the EU to remain successful in a fast evolving global economy (EC, 2007). Moreover, education is a way to demonstrate abilities to the market by acting as a signal for employers to choose workers with expected better productivity. Blanco & Lopez Boo (2010) suggest that there is a slightly positive correlation in disadvantaged workers between having ICT skills and the probability of receiving a return call while searching for job.

Therefore, education and training can be a relevant way to increase general and specific worker competences required by the market while being an efficient way to signal higher productivity to employers. This strong relationship between education, ICT skills, employment and productivity is likely to be more profound in the developed economies, such as the EU, which depend more heavily on a highly skilled labour force. Therefore, a deeper understanding of the effect of acquiring abilities through ICT to increase productivity (measured through competitiveness and unemployment rates) within the EU and comparing the EU to other countries is crucial to creating suitable public policies related to education. It will assist in assessing the benefits of properly integrating technology into the educational environment while understanding the consequences of not doing so.

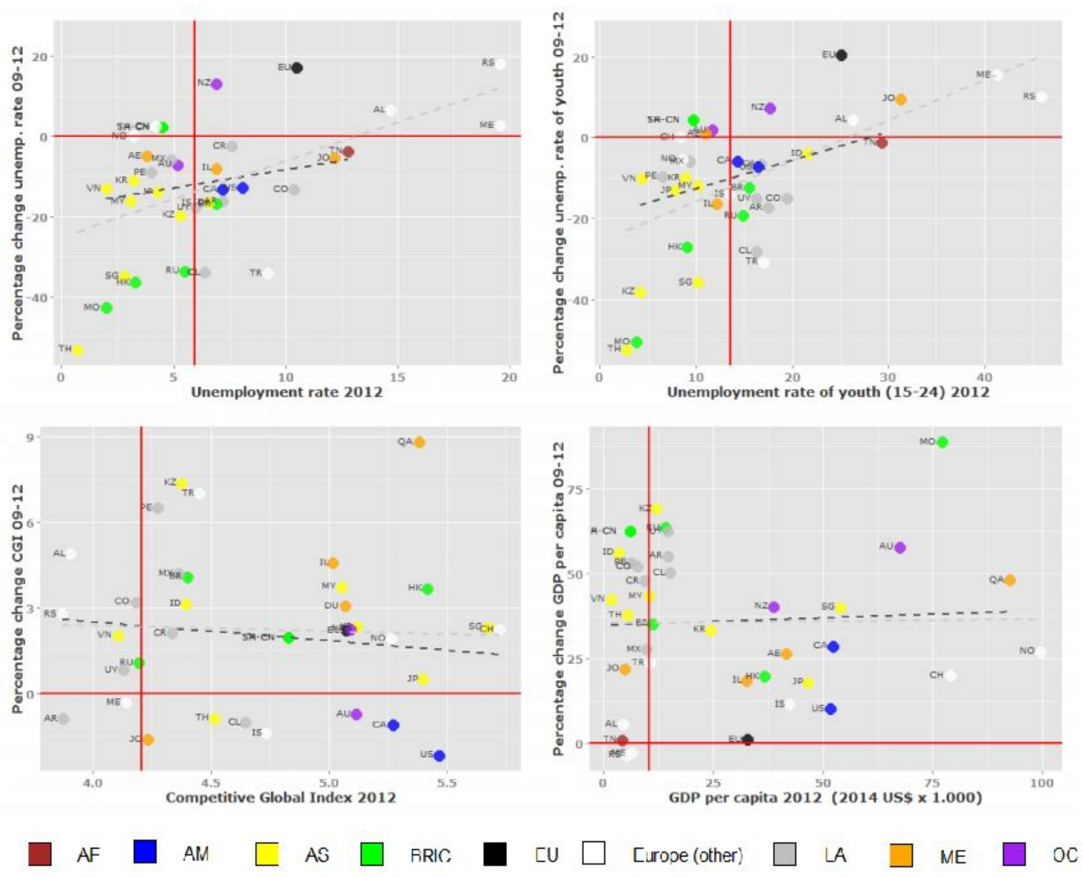
5.1. International benchmarking of educational technology

The goal of this section is to analyse the situation of education, particularly educational technology, in European countries compared to other countries, and the subsequent consequences on employment, productivity and economic growth. To achieve this goal, an analysis is carried out by combining data about technological education, education performance, skills, and macro socio-economic indicators (Eurostat, 2014a, 2014c; Internet World Stats, 2014; OECD, 2014a; The World Bank, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g; WEF, 2014). First, a comparative analysis of relevant socio-economic indicators is carried out. Subsequently, an assessment is undertaken pertaining to how these indicators are related to educational achievements. Finally, several educational technology performance measures are included in the analysis to assess the medium-term and top-level consequences of the way technology is currently used in the education system in Europe.

5.1.1. Benchmarking of socio-economic indicators

Europe is facing a challenging situation as can be seen in Figure 19. Comparing the average unemployment rate in the EU to other countries, the level of unemployment in Europe is particularly high and it is growing at the highest rate among the countries analysed. The effect is even more challenging when considering youth unemployment rates. Conversely, there is a group of countries - namely China and other Asian countries - that is performing particularly well with much lower and decreasing unemployment rates. Other developed economies, such as Canada and the US, are also performing better than the EU. GDP per capita in the EU has stagnated with no growth between 2009 and 2012 while China and certain Asian countries have increased GDP per capita by more than 30 per cent during the same period. Only the Competitiveness Global Index (CGI)[9] of Europe remains high and growing, although at lower rates than BRIC (the five major emerging national economies: Brazil, Russia, India, China, and South Africa) and Asian countries.

Figure 19: EU27 macro-indicators value and trend compared to other countries



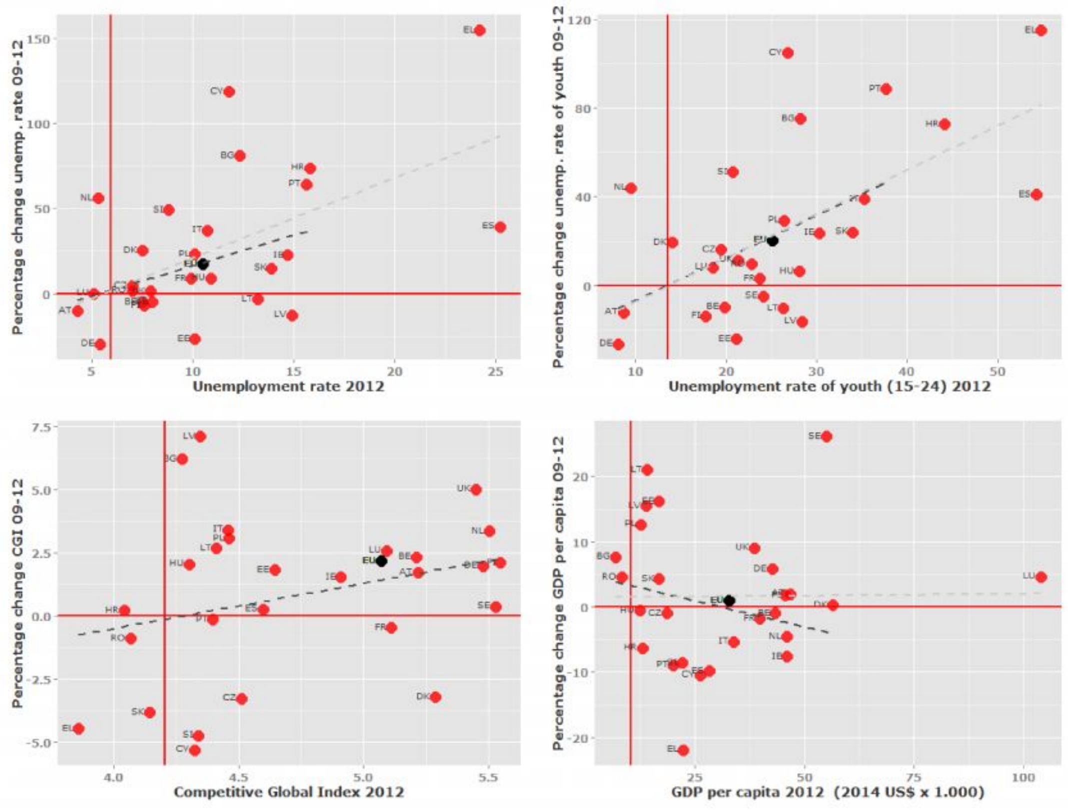
Source: Compiled by the authors based on (The World Bank, 2014b, 2014f, 2014g; WEF, 2014)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average CGI has been calculated using a weighted average by GDP (The World Bank, 2014a). Red lines show the worldwide average (x-axis) and the 0 per cent change (y-axis).

Moreover, within the EU, there are strong disparities among Member States as can be seen in Figure 20. Only 4 countries are below the worldwide average unemployment rate, and only 3 when considering youth unemployment; further, 20 out of 27 countries have youth unemployment rates higher than 20 per cent, with Spain and Greece surpassing the 50 per cent mark. Half of the countries' GDP per capita has decreased between 2009 and 2012, with Greece's GDP per capita decreasing by more than 20 per cent. Only 5 countries have experienced more than 10 per cent growth during the same period, with Sweden and Lithuania's GDP per capita having increased by more than 20 per cent. Increasing unemployment rates and GDP stagnation go hand-in-hand in the EU.

[9] The CGI is an index developed by the World Economic Forum to estimate the level of productivity and competitiveness of countries by using a weighted average of different concepts, such as institutional environment, infrastructure, macroeconomic environment, education, markets efficiency, market size, innovation, and technological readiness.

Figure 20: EU27 countries' macro-economic indicators value and trend



Source: Compiled by the authors based on (The World Bank, 2014b, 2014f, 2014g; WEF, 2014)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average CGI has been calculated using a weighted average by GDP (The World Bank, 2014a). Red lines show the worldwide average (x-axis) and the 0 per cent change (y-axis).

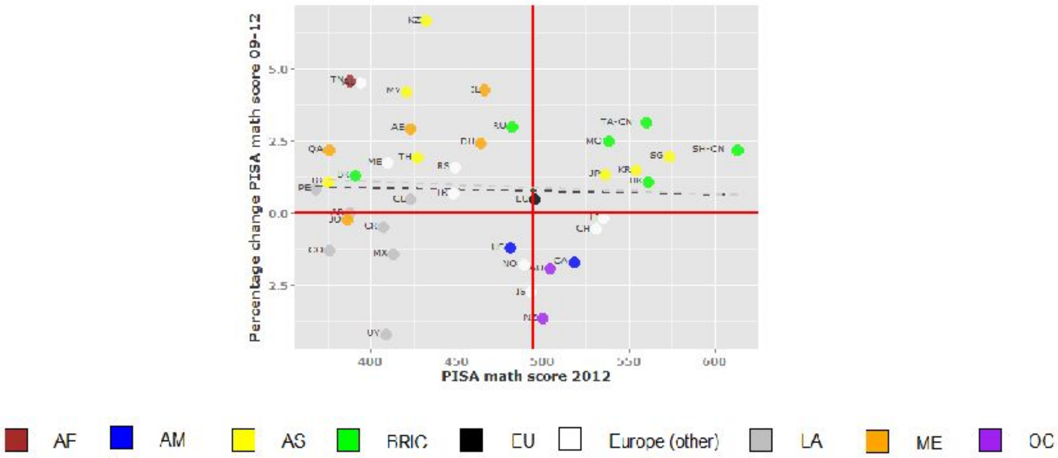
Main Findings

The EU is facing a challenging situation with economic stagnation and high unemployment rates, while China and other Asian countries are performing particularly well; moreover, strong disparities exist among Member States.

5.1.2. Benchmarking of education performance

The analysis focuses on math scores because the influence of technology on math performance has been shown to be greater than that of other subjects (Barrow, Markman, & Rouse, 2009; Michael, 2002). Although the EU is performing average on PISA math scores, and has shown improvements over the last 3 years, certain Asian economies – such as Japan, Korea, Hong-Kong or Singapore - are performing much better and improving faster as shown in Figure 21. Nonetheless, the EU is performing on average very similar to other advanced countries, such as the US, Canada and Australia, while improving slightly faster.

Figure 21: PISA math scores 2012 and trend in EU27 compared to other countries

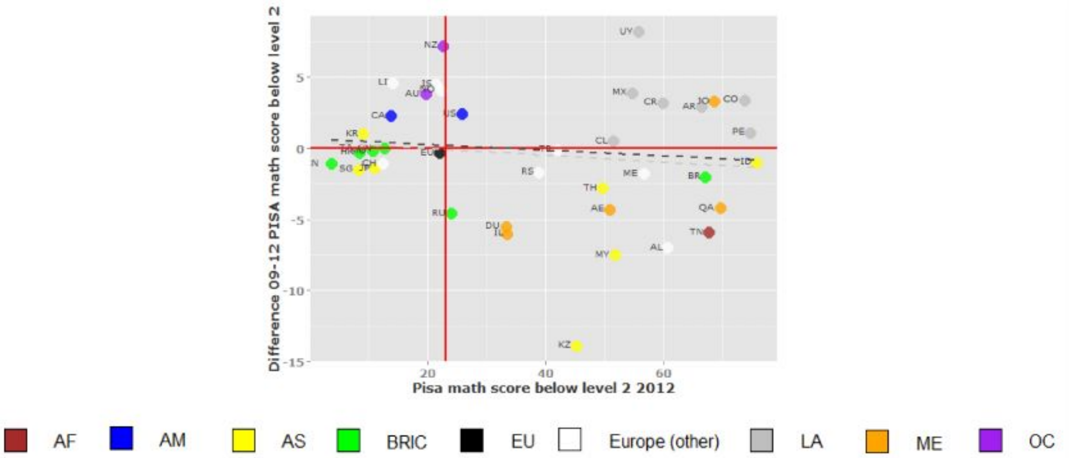


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average (x-axis) and the 0 per cent change (y-axis).

Although the percentage of students below level 2[10] in the EU is average, with no change observed between 2009 and 2012, China[11] and other Asian countries are performing better than the EU, having either a lower number of students performing below level 2 or improving faster, as shown in Figure 22. The performance of other advanced economies is slightly worse than the EU, and Latin American countries perform poorly with higher and growing disparities.

Figure 22: PISA math scores below level 2 in 2012 and trend in EU27 compared to other countries



Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average (x-axis) and the 0 per cent change (y-axis).

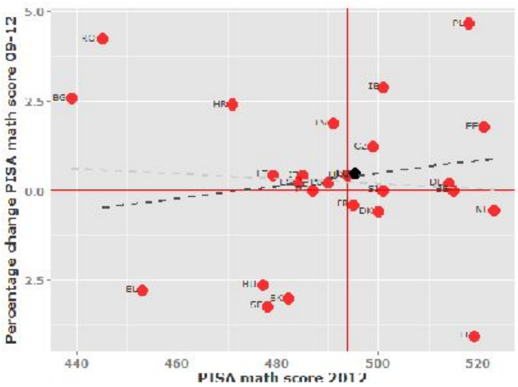
[10] There are 6 proficiency levels in the math score in PISA. Low achievement is defined as performance below level 2 (EC, 2013d). "At Level 2 students can interpret and recognise situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures, or conventions. They are capable of direct reasoning and making literal interpretations of the results" (OECD, 2013a, p. 41)

[11] Reference to China's education performance indicators in this chapter, refers to the following areas assessed by PISA: Taipei, Hong Kong, Macau and Shanghai.

Within the EU, while half of the Member States are located around the average, Romania and Bulgaria are performing lower, although improving, Poland, Ireland and Estonia are performing much better and improving faster, and Finland is performing better however has worsened since 2009. Further, there is a group of 6 countries that are performing lower than average and declining as can be seen in

Figure 23.

Figure 23: PISA scores 2012 and trend in EU27 countries

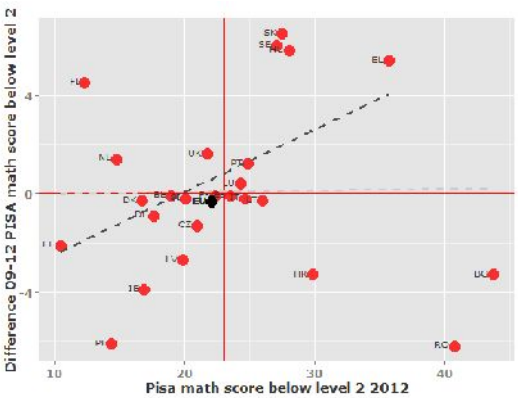


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average (x-axis) and the 0 per cent change (y-axis).

Disparities also arise when analysing the percentage of students below level 2 in PISA math scores within the EU. While most of the countries are located around the average, Romania and Bulgaria are performing much lower but improving, Estonia is performing very well, and Finland is performing well but declining. In addition, there is a group of 4 countries (Slovakia, Sweden, Greece, and Hungary) that are performing lower than average and worsening as can be seen in Figure 24.

Figure 24: PISA math scores below level 2 in 2012 and trend in EU27 countries



Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average (x-axis) and the 0 per cent change (y-axis).

Main Findings

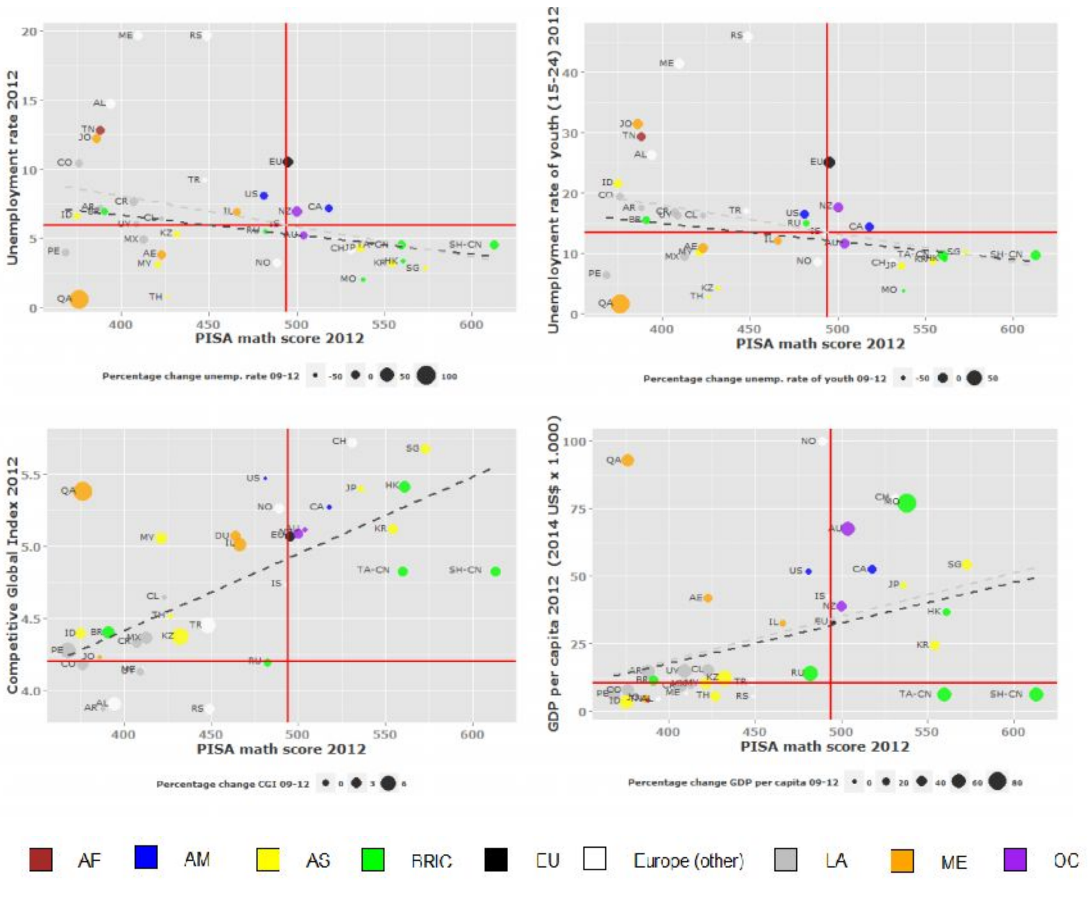
The EU's performance in education is weak, particularly compared to China and other Asian economies, both in terms of the average score and in the percentage of low performing students. While the former suggests poor education performance, the latter may indicate that the EU is fostering inequalities through education.

There are also strong disparities among EU countries in education performance, thus making it difficult to develop one-size-fits-all policies.

5.1.3. Relationship between education performance and socio-economic indicators

There is a clear correlation between math PISA scores and macroeconomic indicators, particularly with competitiveness, as shown in Figure 25. China and other Asian countries are performing better in math PISA scores and are growing faster in GDP per capita while displaying lower unemployment rates. Interestingly, the economies of the US and Canada perform better in most of the macro indicators having similar math scores as the EU.

Figure 25: Relationship between PISA math score in 2012 and macro-indicators in EU27 compared to other countries

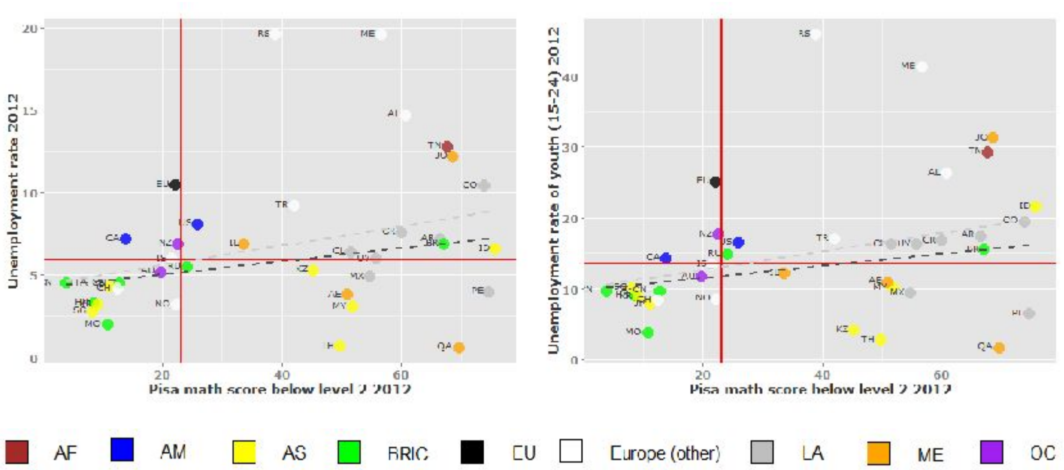


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a; The World Bank, 2014a, 2014b, 2014f, 2014g; WEF, 2014)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The size of the circle represents the percentage change between 2009 and 2012 of the variable in the y axis. The EU27 average CGI has been calculated using a weighted average by GDP (The World Bank, 2014a). The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a).
Red lines show the OEDC average (x-axis) and worldwide average (y-axis).

Another interesting aspect is the relationship between the percentage of students below level 2 in PISA math scores and unemployment. There is a slightly positive relationship between the two, as can be seen in Figure 26. Interestingly, the relationship is much worse for the EU compared to other advanced economies and some Asian countries. Disparities in education achievement seem to have a deeper effect on unemployment in the EU compared to those countries. It may suggest that the EU economy is more dependent on having highly skilled workers to tackle unemployment.

Figure 26: Relationship between percentage of students below level 2 in PISA math scores and unemployment in EU27 compared to other countries

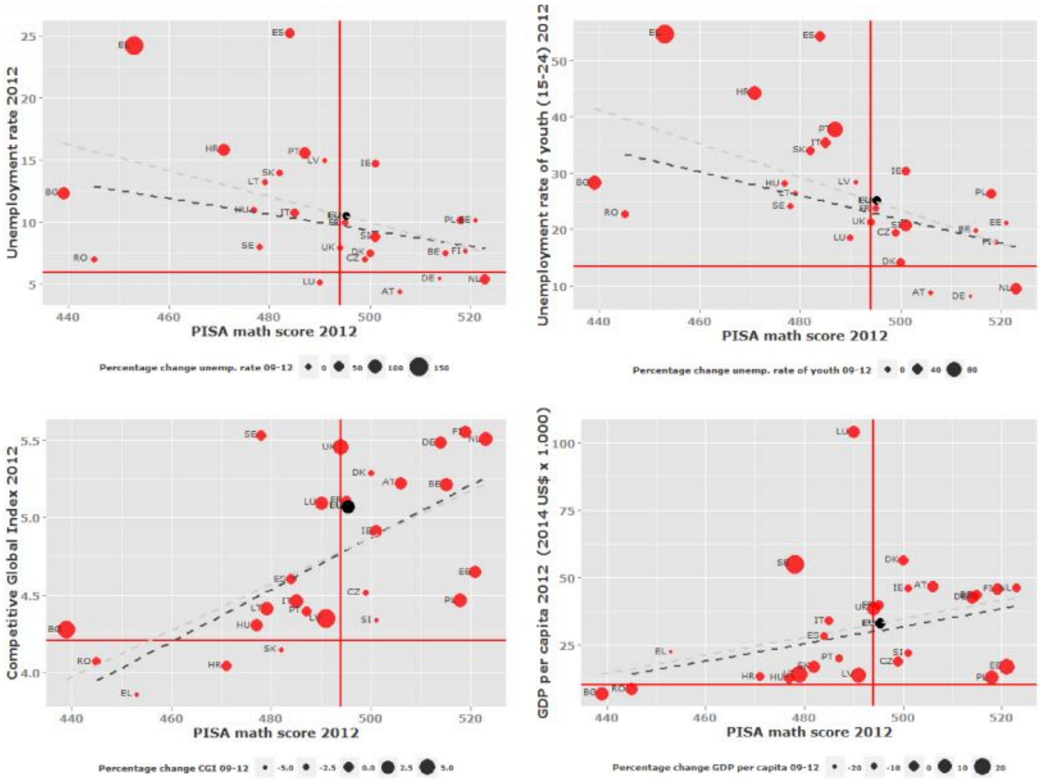


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a; The World Bank, 2014a, 2014b, 2014f, 2014g; WEF, 2014)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The size of the circle represents the percentage change between 2009 and 2012 of the variable in the y axis. The EU27 average CGI has been calculated using a weighted average by GDP (The World Bank, 2014a). The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average (x-axis) and worldwide average y-axis).

When analysing the results pertaining to EU countries, strong disparities are evident (see Figure 27). Lower math PISA scores and higher unemployment rates are strongly related in a number of EU countries, namely Greece, Spain, Hungary, Portugal, Italy and Slovakia, particularly for youth. EU countries with low math PISA scores also show lower levels of competitiveness. Conversely, several countries, such as Finland, Denmark, Netherland, Belgium and Austria high math PISA scores and high level of competitiveness. These findings suggest that within the EU, higher educational achievements are more intensely related to better macro-economic indicators than worldwide. It makes sense if considering that the EU is a highly skilled economy and therefore, further worsening of education in the EU may have a more profound effect than in other economies.

Figure 27: Relationship between PISA math score in 2012 and macro-indicators in EU27 countries

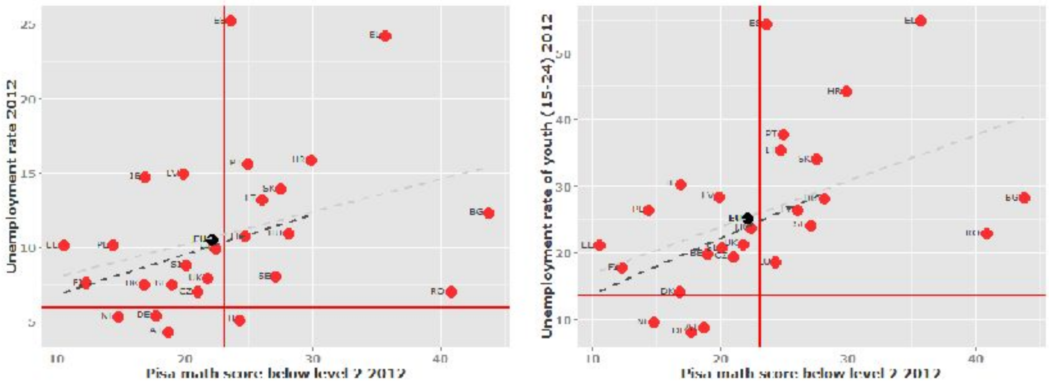


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a; The World Bank, 2014a, 2014b, 2014f, 2014g; WEF, 2014)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The size of the circle represents the percentage change between 2009 and 2012 of the variable in the y axis. The EU27 average CGI has been calculated using a weighted average by GDP (The World Bank, 2014a). The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average (x-axis) and worldwide average (y-axis).

Interestingly, the relationship between the percentage of students below level 2 in PISA math scores and unemployment is much higher within the EU compared to worldwide. The slightly positive relationship seen in the global scene in Figure 26 has turned into a stronger positive relationship within the EU as shown in Figure 28. Again, it suggests the strong dependency of the EU economy on having a highly skilled labour force.

Figure 28: Relationship between percentage of students below level 2 in PISA math scores and unemployment in EU27 countries

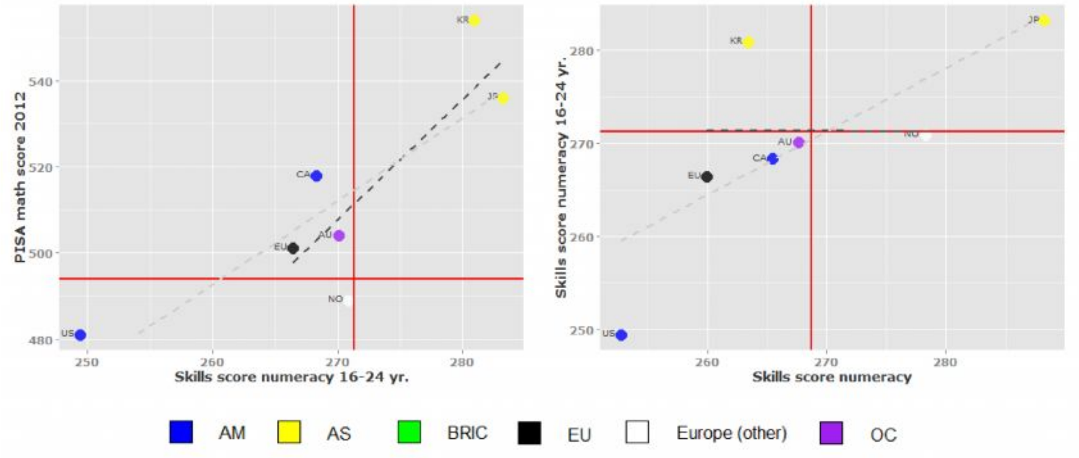


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a; The World Bank, 2014a, 2014b, 2014f, 2014g; WEF, 2014)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The size of the circle represents the percentage change between 2009 and 2012 of the variable in the y axis. The EU27 average CGI has been calculated using a weighted average by GDP (The World Bank, 2014a). The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average (x-axis) and worldwide average (y-axis).

There is a strong relationship between education and the skills of youth as shown in the left side of Figure 29. Higher PISA math scores are strongly related to higher scores of numeracy skills of youth aged 16 to 24. Improving education can lead to youth having better skills. A good example is Korea; the only country that has substantially improved the skills of youth in comparison to adults, as can be seen in the right side of Figure 30.

Figure 29: Relationship between education and skills by age in EU14 compared to other countries

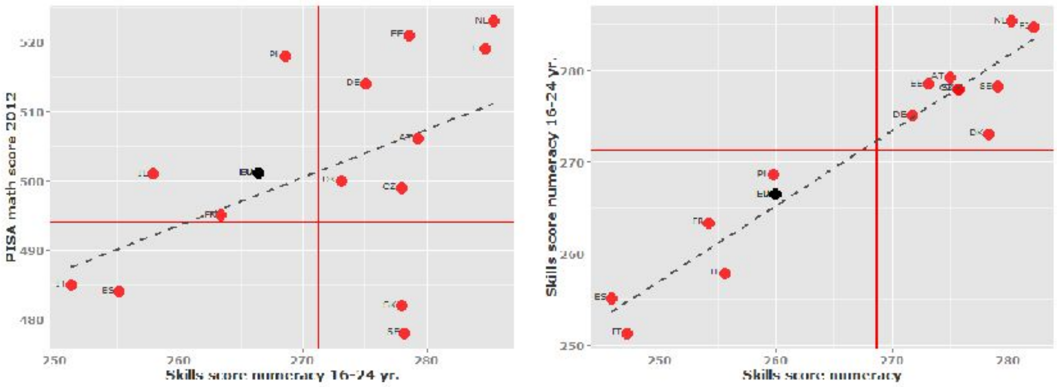


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014a; The World Bank, 2014b, 2014e, 2014g)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU average score has been calculated using a weighted average by population aged 16 to 64 at 2013 (Eurostat, 2014c).
Red lines show the show the PIAAC average.

Within the EU, there is also a clear relationship between education and skills of youth as shown in the left side of Figure 30. Higher PISA math scores are related to higher scores of numeracy skills of youth aged 16 to 24. However, it seems that the EU is not drawing upon education to improve adult skills as seen in the right side of the same Figure. The average improvement in the EU between scores of adults and scores of youth is small, and no country in the EU stands out with a substantial improvement.

Figure 30: Relationship between education and skills by age in EU14 countries

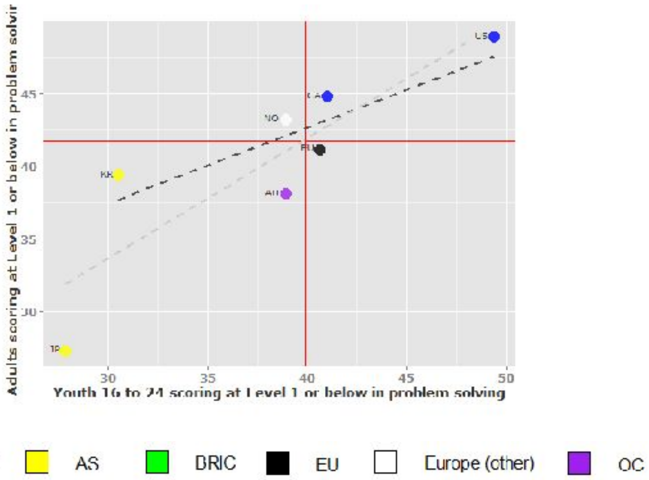


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014a; The World Bank, 2014b, 2014e, 2014g)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU average score has been calculated using a weighted average by population aged 16 to 64 at 2013 (Eurostat, 2014c).
Red lines show the show the PIAAC average.

Another important fact is how well youth are performing with regards to problem solving in technology rich environments in comparison with adults. It signals whether technology is being used in education in a manner which enables students to acquire technological skills that are applicable to the work place. This relationship is shown in Figure 31. Europe is performing slightly better than average with regards to adults but slightly worse than average with regards to youth. Other advanced economies, such as the US and Canada, are performing worse than Europe. However, Japan and Korea are performing much better, particularly among youth, something that may pose a strong challenge for European economies in the medium-term. In fact, one of the challenges confronting the educational system in Europe, is the low digital competence of students (L. Johnson et al., 2014).

Figure 31: Relationship between percentages of adults scoring at level 1 or below in problem solving in technology rich environments[12] by age in 2012 in EU14 compared to other countries



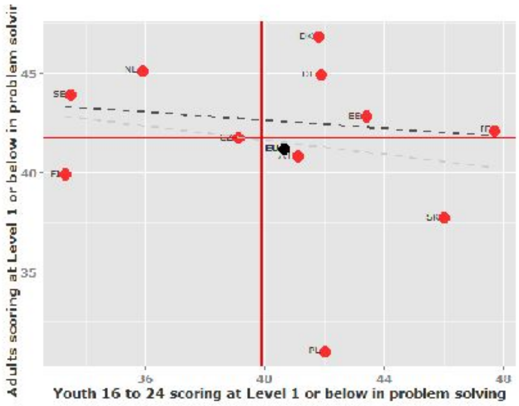
Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014a; The World Bank, 2014b, 2014e, 2014g)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU average score has been calculated using a weighted average by population aged 16 to 64 at 2013 (Eurostat, 2014c).
Red lines show the PIAAC average.

Within Europe, there is a group of countries that are performing worse in terms of developing the skills of youth in comparison to adults; this raises concerns about how the educational systems in these countries are helping students to acquire the necessary ICT abilities. Only the Netherlands, Sweden, and Finland are substantially improving the skills of youth compared to adults. As a result, generally speaking, Europe is stagnating (see Figure 32).

[12] PS-TRE assesses the cognitive processes of problem solving: goal setting, planning, selecting, evaluating, organizing and communicating results. The environment in which PS-TRE assesses these processes is meant to reflect the reality that digital technology has revolutionized access to information and communication capabilities over the past decades (IES, 2013).

Figure 32: Relationship between percentages of adults scoring at level 1 or below in problem solving in technology rich environments by age in 2012 in EU14 countries



Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014a; The World Bank, 2014b, 2014e, 2014g)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU average score has been calculated using a weighted average by population aged 16 to 64 at 2013 (Eurostat, 2014c).
Red lines show the PIAAC average.

Main Findings

There is a strong relationship between education performance, including low performing students, and macro-economic indicators; this relationship seems to be more intense within the EU, particularly regarding unemployment rates.

Education and skills of adults are closely related, and no EU country has substantially improved the skills of youth in comparison to adults. It may suggest that education in the EU is not working as expected.

In the EU, the US and Canada, there is a high percentage of youth with low problem solving skills in technology rich environments; moreover, the situation is worsening for 50 per cent of EU countries. It suggests that the level of digital competence among EU students is low.

5.1.4. Analysis of the relationship between technological education and education performance

Once the relationship between economic development and education achievements has been established, the next step is to analyse how educational technology is affecting educational performance and whether the relationship differs among countries. In order to conduct this analysis, the following two variables are used: the number of computers per student and expected computer use.[13]

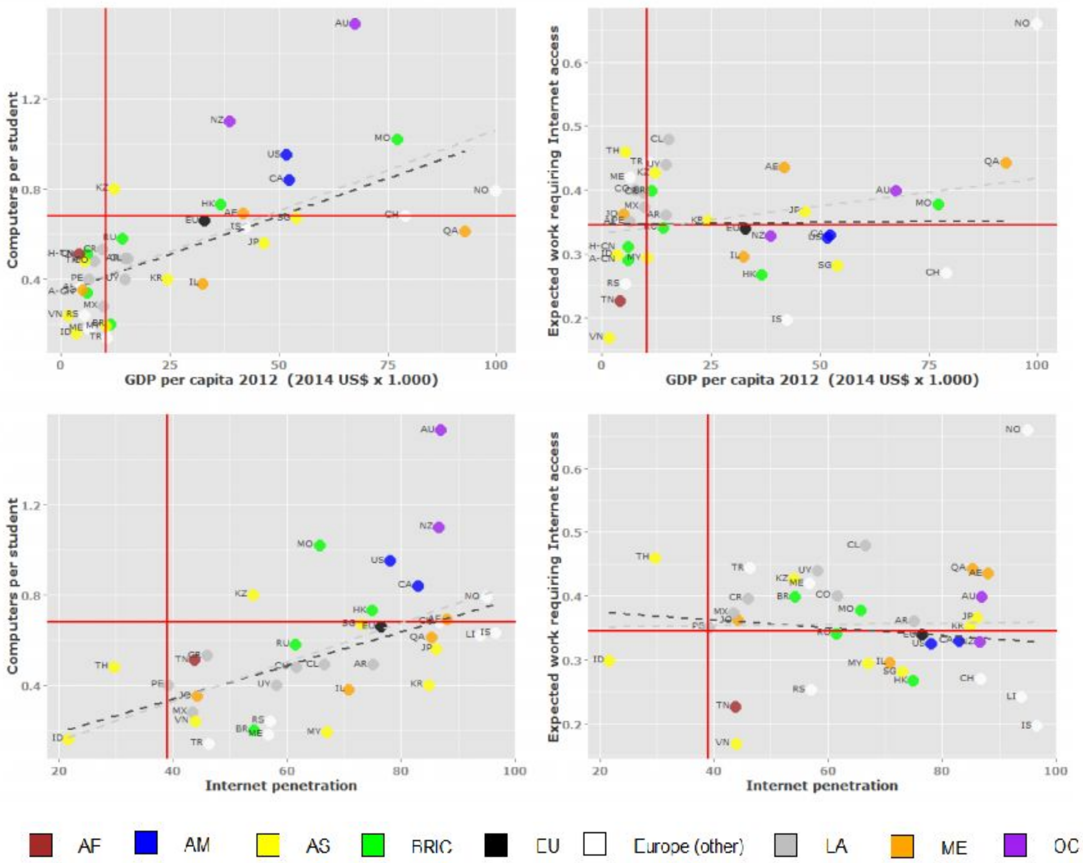
The number of computers per students is related to the country's wealth. Countries with higher GDP per capita have, on average, a higher number of computers per student. However, the relationship is less clear when considering expected computer use as seen in Figure 33. It suggests that poorer countries, although having fewer computers per student, make greater use of the available resources to achieve higher levels of use.

[13] Computer use is estimated by using the school principals' report regarding the amount of time a 15-year-old student requires access to the Internet in order to: (1) work during lessons; (2) complete homework; and (3) work on assignments and projects (OECD, 2014b).

A similar pattern arises when analysing the relationship between computers per student and Internet penetration. Higher levels of Internet penetration are related to higher numbers of computers per student; however, there is no clear pattern when considering computer use. Countries with lower GDP per capita and lower Internet penetration rates can draw upon fewer computers at school to achieve similar levels of computer use.

The EU average is slightly lower than the average worldwide both for computers per student and computer use. Other advanced countries, such as the US, Canada, Australia and New Zealand have much higher rates of computers per student, although their computer use is similar to the EU. Surprisingly, Latin American countries, which have low levels of computers per student, have higher rates of expected computer use.

Figure 33: Relationship between macro-indicators and technology penetration at schools in EU27 compared to other countries



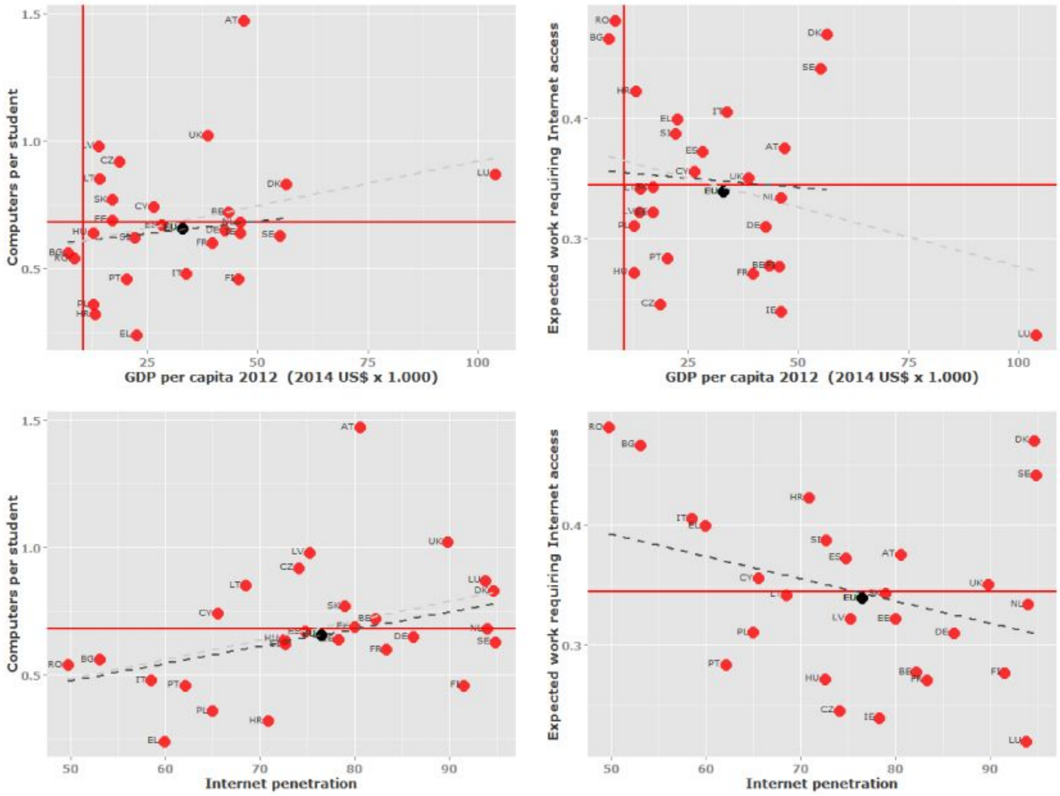
Source: Compiled by the authors based on (Eurostat, 2014a; Internet World Stats, 2014; OECD, 2014a; The World Bank, 2014b)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the worldwide average (x-axis) and OEDC average (y-axis).

Within the EU, there is a slightly positive relationship between GDP per capita and Internet penetration as well as computers per student, and a slightly negative relationship with computer use as shown in Figure 34. However the relationship does not seem to be significant. It could be explained by the higher GDP per capita and high levels of Internet penetration in EU countries. Once a threshold is achieved, there are no further differences in technology penetration and computer use.

Romania and Bulgaria stand out by having the highest levels of computer use, while Luxembourg has the lowest.

Figure 34: Relationship between macro-indicators and technology penetration at schools in EU27 countries

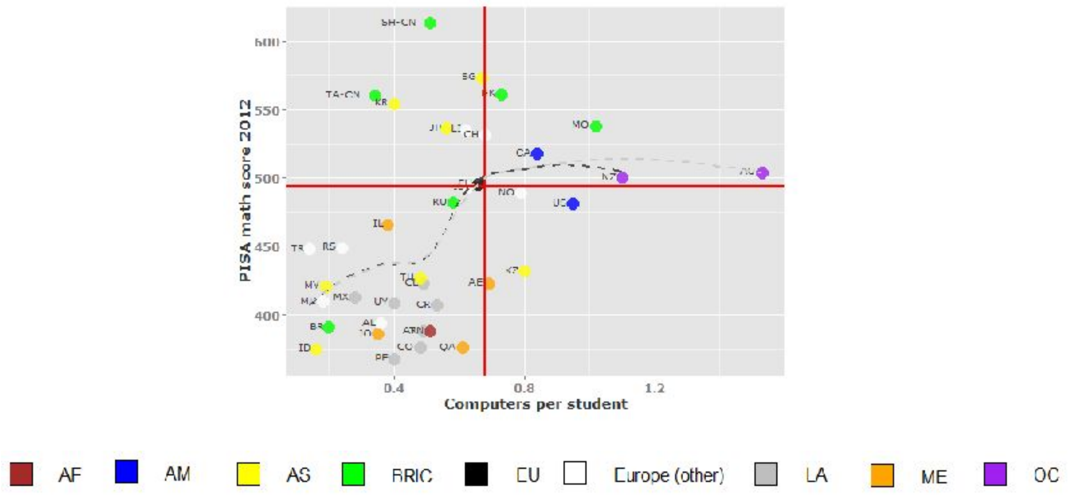


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the worldwide average (x-axis) and OEDC average (y-axis).

It is particularly interesting to analyse the relationship between technology use and academic achievements. In considering computers per student, the relationship is unclear as shown in Figure 35. Worldwide, there is a group of countries (mainly Latin American) that are performing poorly while having fewer computers per student. The EU, and particularly the most advanced economies, have higher levels of computers per student without significant differences in academic achievement. The group of BRIC (except Brazil) and certain Asian countries have higher levels of academic achievements with lower levels of computers per students. It suggests that the number of computers per student is weakly related to academic achievements, challenging policies solely focused on providing as many computers as possible.

Figure 35: Relationship between technology penetration at schools and PISA math scores in EU27 compared to other countries

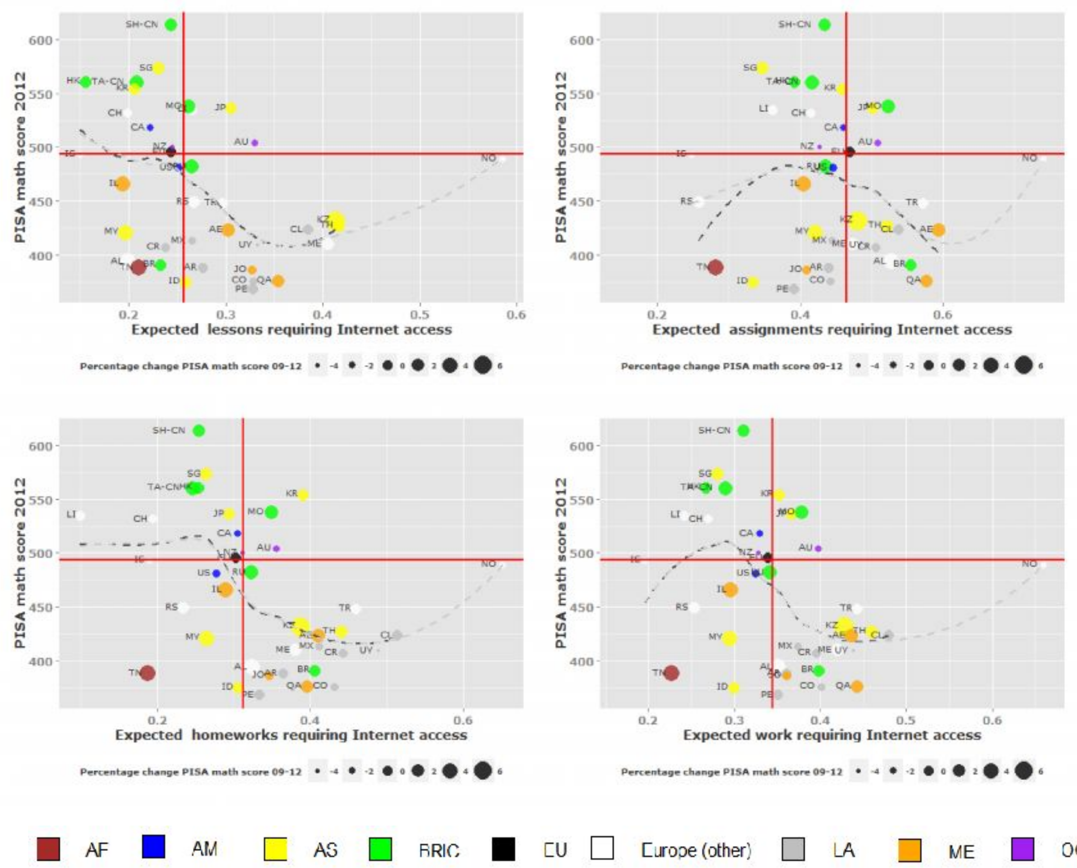


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average.

A clear pattern is found when analysing computer use as shown in Figure 36. Very high levels of expected computer use are associated with lower academic performance. Countries performing very high in math PISA scores make average use of computers in class, particularly for assignments, as well as at home. Most BRIC and the aforementioned Asian countries —some of them being pervasive technology societies-, have the highest academic scores while having moderate levels of expected computer use. On the other hand, less developed countries, particularly in Latin America; show high levels of expected computer use but achieve poor academic achievements. There is evidence that providing computers to households in countries with low technology penetration can contribute to the computers having no effect (Malamud & Pop-Eleches, 2011) or even having a negative effect (Vigdor & Ladd, 2010) on the academic achievement of children. The EU scores average, both in academic performance and in computer use. Other advanced economies, such as the US, Canada, and Australia, have similar scores to that of the EU. The main conclusion is that higher levels of use are not related to better academic performance. In fact, higher levels of expected computer use are associated with weak academic performance.

Figure 36: Relationship between expected computer use in education and PISA math scores in EU27 compared to other countries

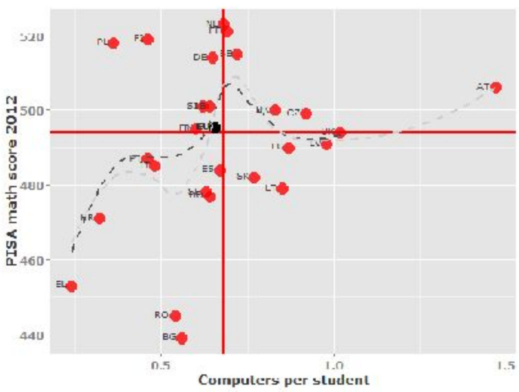


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average.

When analysing the relationship between computers per students and math PISA scores within the EU, the pattern suggests that fewer computers per student are related to lower achievements; in addition, countries performing better have approximately the same numbers of computers per student as the EU, as shown in Figure 37. However, the pattern is quite unclear.

Figure 37: Relationship between technology penetration at schools and PISA math scores in EU27 countries

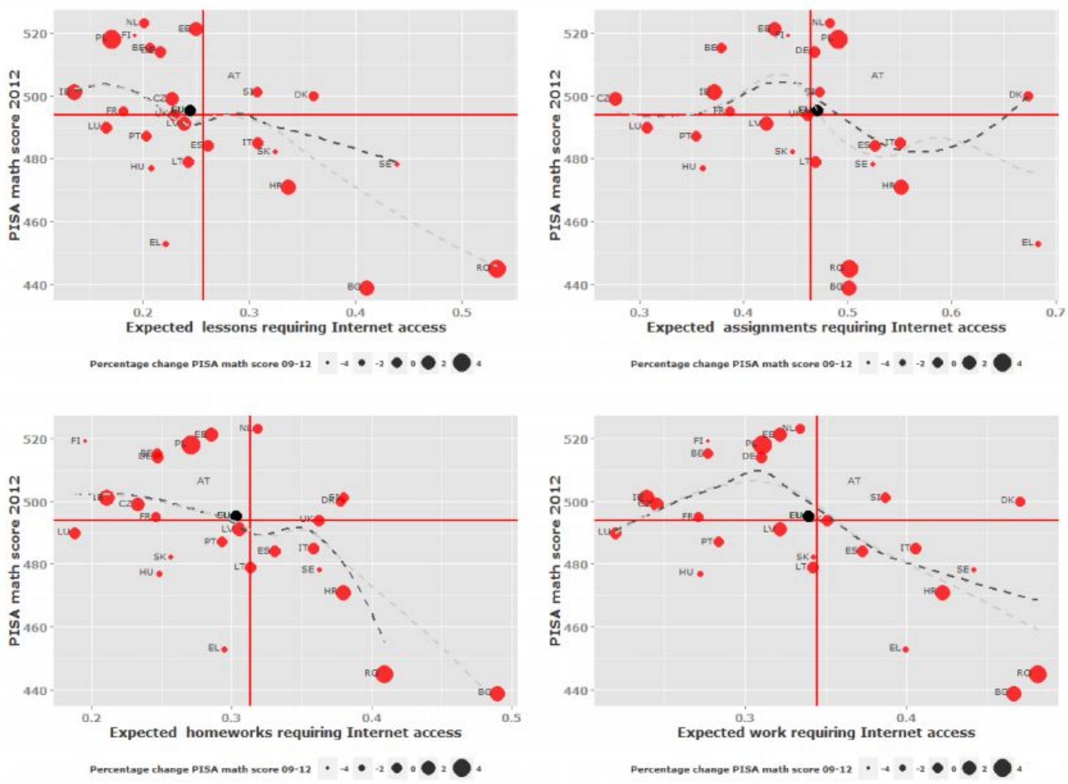


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average.

A slightly clearer pattern emerges when considering the relationship between math PISA scores and computer use among EU countries (see Figure 38). Very low and very high levels of expected computer use are associated with lower academic performance. This is particularly relevant for Romania, Bulgaria and Hungary. The best performing countries are those using computers slightly lower than average in the EU, namely Poland, Netherland, Denmark and Estonia. It suggests that the best results stem from a thoughtful use of technology in the education environment. It is not about filling the classrooms with computers or forcing teachers and students to use them; rather, it is about thinking about how to effectively integrate the technology in the educational system.

Figure 38: Relationship between expected computer use in education and PISA math scores in EU27 countries

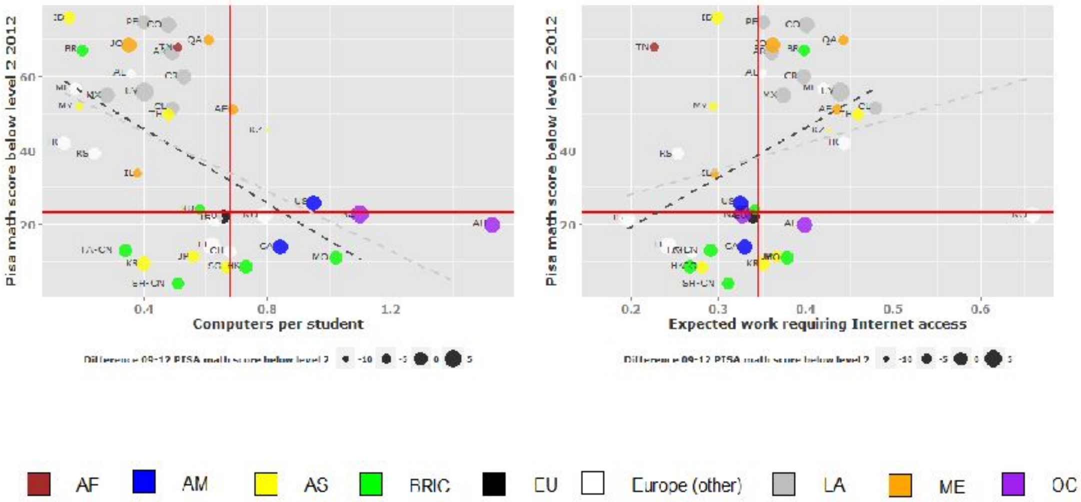


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a). Red lines show the OEDC average.

It is also interesting to analyse the relationship between technology use and the percentage of students with weak education achievements, as shown in Figure 39. Countries with fewer computers per student are associated with a higher percentage of low performing students. Conversely, expected computer use is associated with a higher percentage of low performing students. A group of countries, mainly from Latin America, although having fewer computers per student show high levels of computer use while having a substantially higher number of students performing below level 2. Most BRIC and certain Asian countries show fewer computers per student and lower computer use to substantially diminish the percentage of low performing students. Other advanced economies, with high number of computers per students show average use and average performance. Europe scores average on computers per student, computer use and percentage of students performing below level 2. Again, higher levels of computer use are not directly associated with improving academic achievements of low performing students. Although it is hard to conclude that higher levels of computer use lead to education disparities, the main conclusion is that it is not the level of use, but other factors involving how technology is effectively used that can affect educational performance and inequalities.

Figure 39: Relationship between technology use and percentage of students performing below level 2 in PISA math scores in EU27 compared to other countries

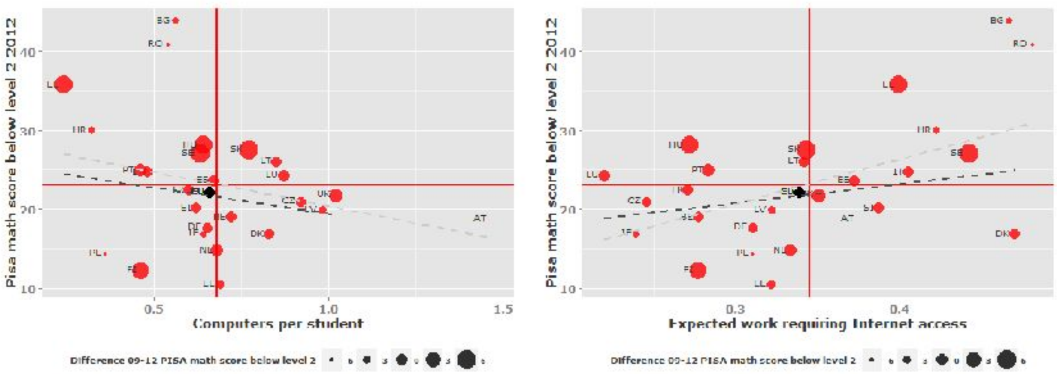


Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta.
The EU27 average scores has been calculated using a weighted average by students aged 15 at 2012 (Eurostat, 2014a).
The size of the balls represent the change in percentage points in students below level 2 in math PISA scores between 2009 and 2012
Red lines show the OEDC average.

A similar, although much smoother, pattern occurs when analysing countries within the EU, as seen in Figure 40. There is a slightly negative relationship between computers per student and percentage of low performing students and a slightly positive relationship with expected computer use among EU countries. It is possible that higher technology penetration in EU countries diminishes the effect of different levels of technology use at schools on educational inequalities. However, the main conclusion persists: what is most important is not the quantity of technology which schools possess; rather, it is the manner in which the technology is used that matters most.

Figure 40: Relationship between technology use and percentage of students performing below level 2 in PISA math scores in EU27 countries



Source: Compiled by the authors based on (Eurostat, 2014a; OECD, 2014a)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta. .
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The size of the balls represent the change in percentage points in students below level 2 in math PISA scores between 2009 and 2012
Red lines show the OEDC average.

Main Findings

Worldwide, while the number of computers per student depends on GDP per capita and Internet penetration, the level of use of those computers does not.

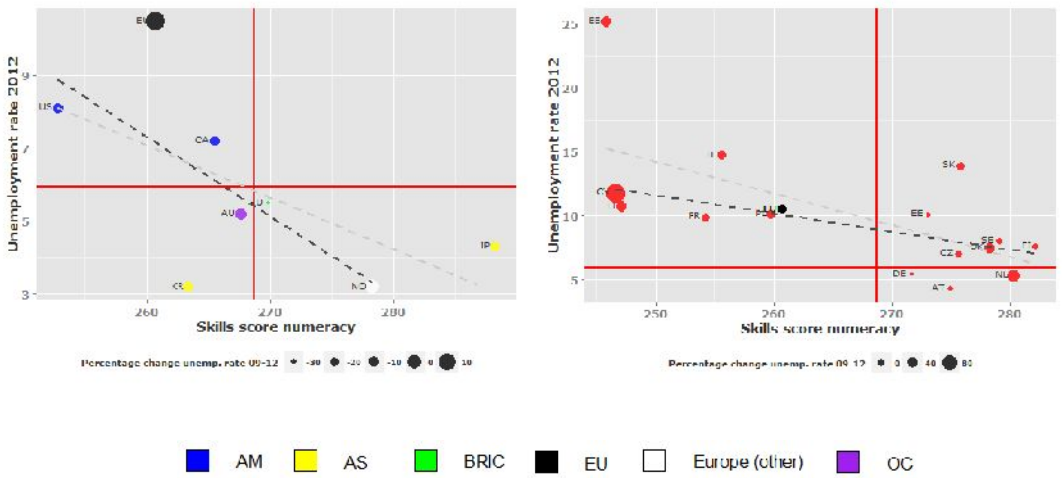
Within the EU, there is not a clear relationship between economic indicators of the countries and technology penetration and use at the schools.

Worldwide and within the EU, the best performing countries in terms of academic achievement tend to use computers in education moderately.

5.2. Analysis of lifelong learning in EU countries

Education is not only about schools; rather it is about improving adult skills throughout their working life. High unemployment rates and an ageing population are two of the main challenges facing Europe. Training and lifelong learning are expected to play a role in tackling those problems by providing new skills to unemployed persons in order to assist their integration into the labour market, and by retraining older workers to be able to catch up with new job requirements. Lifelong learning can help EU workers to meet global labour requirements, thus contributing to guaranteeing employability. In fact, lower performance in numeracy skills and higher unemployment rates are related, as demonstrated in Figure 41. This is particularly relevant for the EU, as it has a much higher average unemployment rate than other advanced economies with similar scores; moreover, it is especially relevant for countries such as Spain and Ireland.

Figure 41: Relationship between numeracy skills and unemployment rates in EU14 and compared to other countries

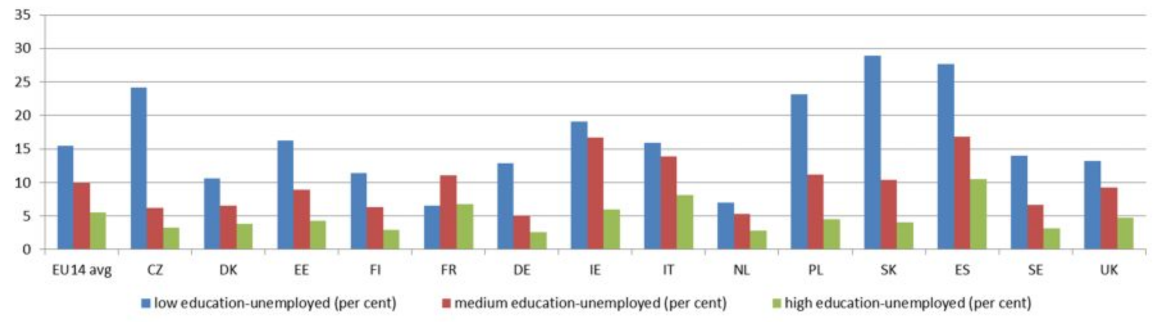


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014a; The World Bank, 2014b, 2014e, 2014g; WEF, 2014)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU average score has been calculated using a weighted average by population aged 16 to 64 at 2013 (Eurostat, 2014c)..
The size of the circle represents the percentage change between 2009 and 2012 of the variable in the y axis.
Red lines show the PIAAC average (x-axis) and the worldwide average (y-axis).

Unemployment affects everyone but hits hardest less educated population as can be seen in Figure 42.

Figure 42: Unemployment rate by education level in 2012

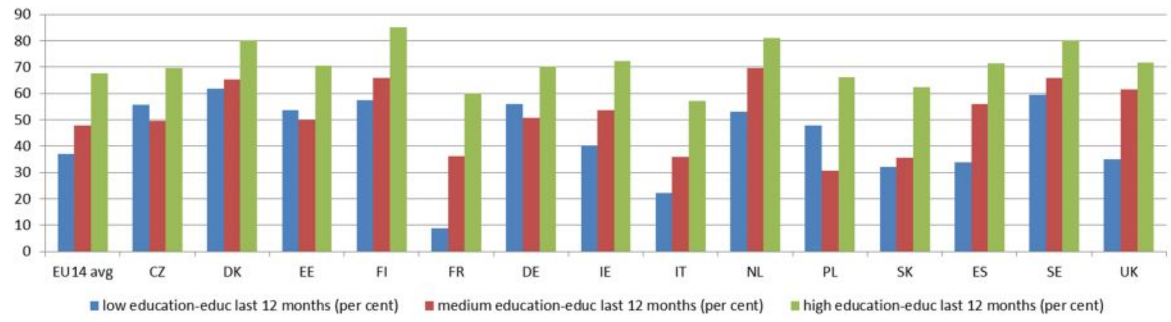


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014b)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU14 average scores has been calculated using a weighted average by population aged 15 to 64 at 2012 (Eurostat, 2014a).

Therefore, less educated people could particularly benefit from lifelong learning. However, less educated populations tend to be much less involved in education activities, as shown in Figure 43.

Figure 43: Participation in education activities over the last 12 months by education level

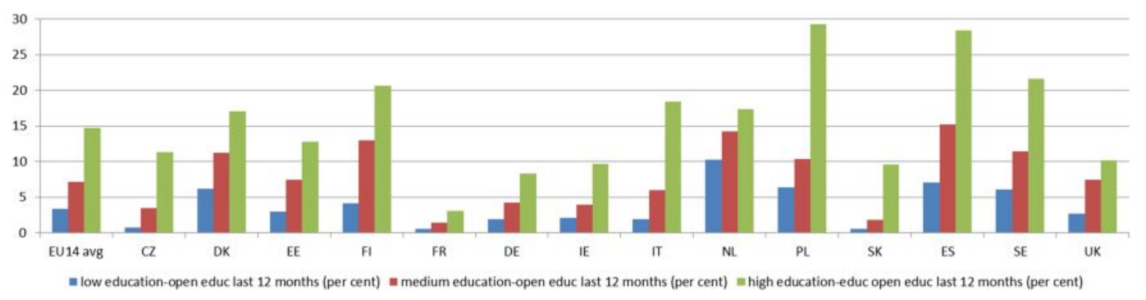


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014b)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU14 average scores has been calculated using a weighted average by population aged 15 to 64 at 2012 (Eurostat, 2014a).

The role of technology in promoting lifelong learning is to provide education in open, convenient formats, which are accessible through the Internet. Open and distance education are considered good means to promote lifelong learning while tackling inequalities. Open and distance education can offer a second chance to low income and disadvantaged populations by providing quality, virtually free education in convenient formats. However the reality is that open and distance education is not reaching less educated populations (see Figure 44). Therefore, it is expected that, in the absence of further policies, open education fostered by technology will contribute to increasing, rather than decreasing, the achievement gap.

Figure 44: Participation in open and distance education over the last 12 months by education level

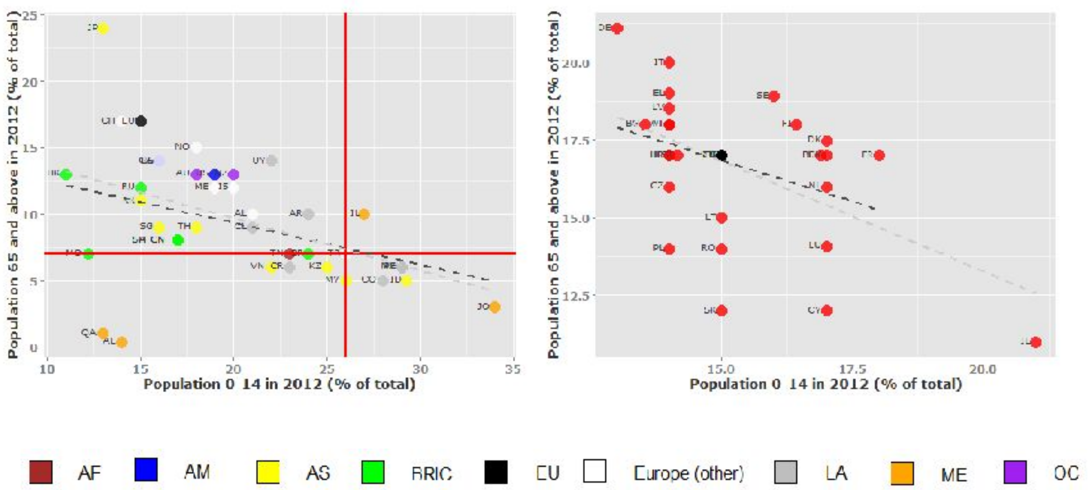


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014b)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU14 average scores has been calculated using a weighted average by population aged 15 to 64 at 2012 (Eurostat, 2014a).

This is particularly worrying in the EU due to an ageing population. Ageing of the population in the EU is a clear trend, as shown in Figure 21. Only Japan has a higher percentage of the population aged over 65; also, the percentage of EU population below the age of 14 is one of the lowest among the countries analysed. All EU member states are performing much worse than the worldwide average. The pattern is particularly worrying for some countries, such as Germany and Italy. Only Ireland has a slightly better performance. This trend affects the overall society and particularly the education sector.

Figure 45: Relationship between population ages (0-14 and 65 and above) in EU27 compared to other countries and within EU27 countries

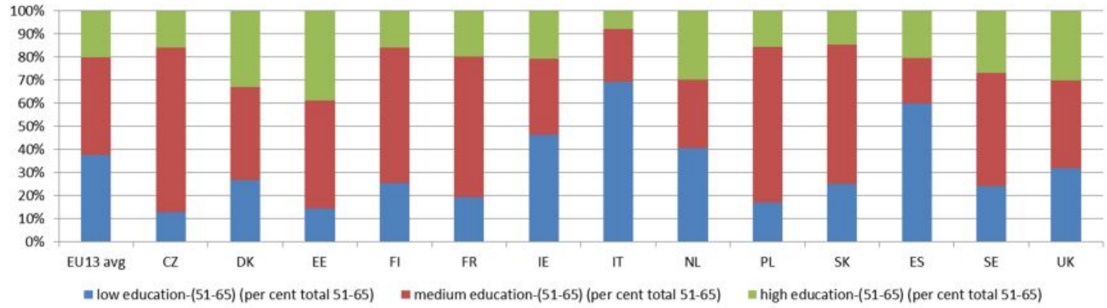


Source: Compiled by the authors based on (The World Bank, 2014c, 2014d)

Note: All countries taking the PISA exam (Annex 10.1) are included in the analysis. EU countries taking the PISA exam are EU28 except Malta.
Red lines show the worldwide average

In the current environment, it is expected than in the years to come, workers will likely have to remain in the labour market until later, and the acquisition of new skills among adults will be crucial to maintaining high productivity levels (Schlotter, Schwerdt, & Wößmann, 2008, p. 4); this is especially the case given the percentage of the population over the age of 50 with low and medium education in the EU is very high, as can be seen in Figure 46. Lifelong learning is particularly relevant in the EU.

Figure 46: Distribution of the population over the age of 50 by education level

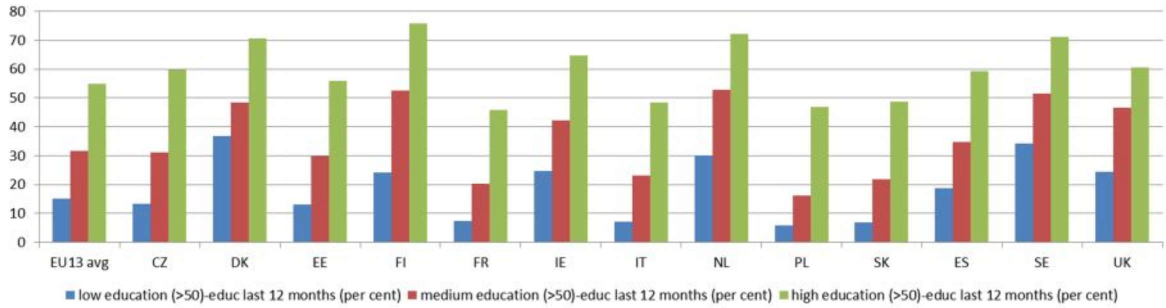


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014b)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC). The EU14 average scores has been calculated using a weighted average by population aged 15 to 64 at 2012 (Eurostat, 2014a).

However, a lack of interest in education among less educated populations is prevalent among older workers. Less educated workers, over the age of 50, are highly unlikely to participate in education activities (see Figure 47).

Figure 47: Participation in education activities of those over the age of 50 by education level

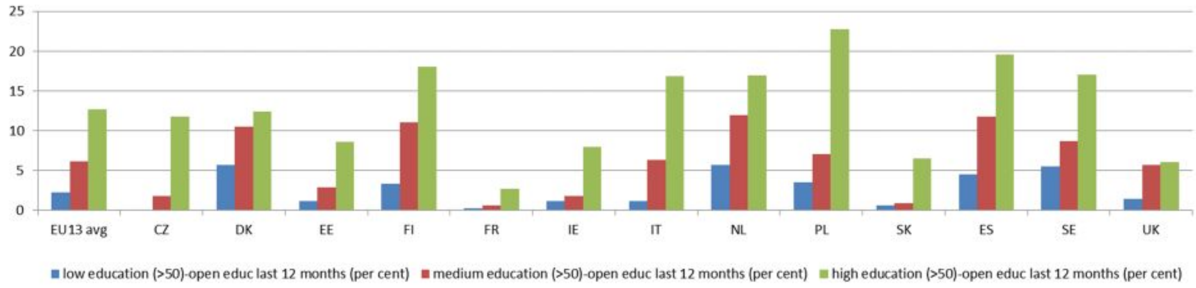


Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014b)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC). The EU14 average scores has been calculated using a weighted average by population aged 15 to 64 at 2012 (Eurostat, 2014a).

Again, this is particularly true for open and distance education — a type of education that could be easily fostered by the use of technology. Older populations are reluctant to participate in open and distance education activities, particularly those with lower levels of education, as can be seen in Figure 48. In fact, age and education remain the key challenges of the digital society because older and less educated populations tend to have lower ICT skills (EC, 2013a). Therefore, it is expected that, in the absence of further policies, open education can contribute to increasing the skills gap of less educated, older workers.

Figure 48: Participation in open and distance education over the last 12 months of those over the age of 50 by education level



Source: Compiled by the authors based on (Eurostat, 2014c; OECD, 2014b)

Note: 14 EU28 countries (Annex 10.1) took part in the 2013 Survey of Adult Skills of the OEDC (PIAAC).
The EU14 average scores has been calculated using a weighted average by population aged 15 to 64 at 2012 (Eurostat, 2014a).

Main Findings

Although education is expected to play a pivotal role in reducing the high unemployment rates in the EU and providing new skills to older workers in a fast evolving environment, the analysis suggests that less educated and older populations are highly unlikely to be involved in lifelong education activities.

This is particularly true with regards to new types of education (open and distance education).

If no further policies are enacted, education fostered by technology (including new types of education) will increase, rather than reduce, the achievement gap.

4

5.3. Limitations

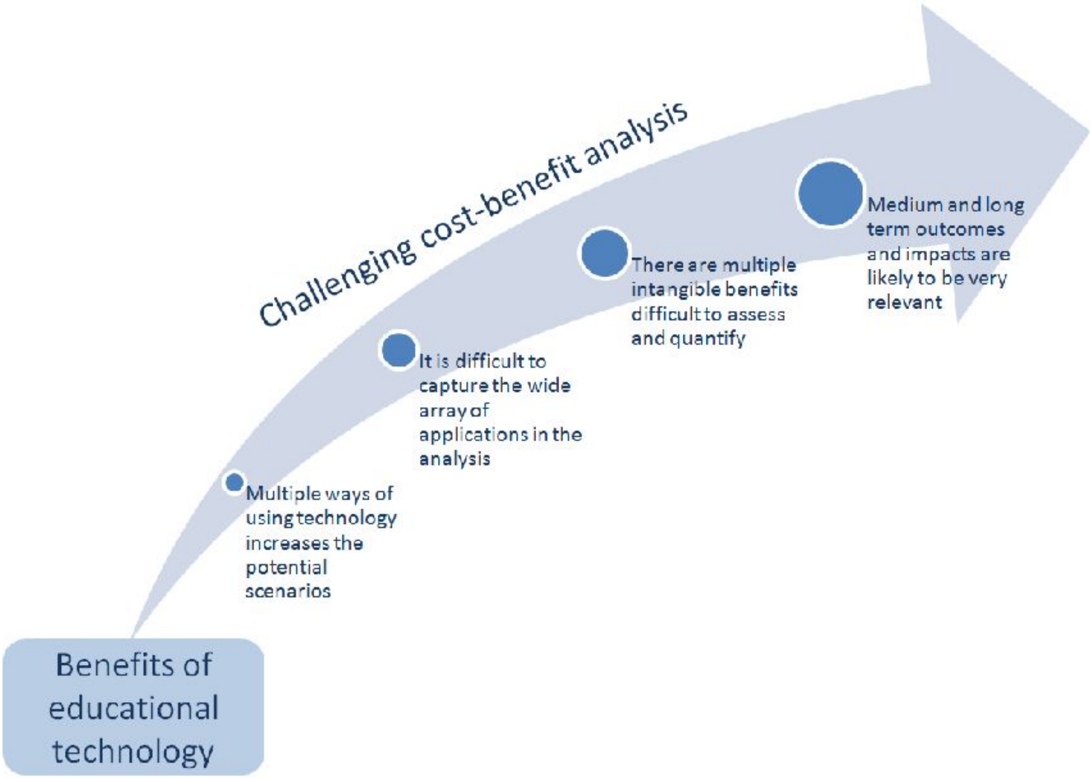
There are some limitations in the analysis that deserve consideration. Educational technology is a complex topic involving multiple factors. While simple quantitative analysis can provide an overall picture, the conclusions should be considered carefully, as only some of these factors have been taken into account. This is even more challenging given this report has attempted to consider all educational levels and technological trends. A lack of specific longitudinal educational data, including different uses of technology and its relationship to academic and lifelong performance, hinders analysing the true casual relationships between how technology is used and the consequences on education and lifelong achievements. In fact, the bivariate analysis carried out in this study does not allow establishing casual relationship between the variables. It is likely that third confounding variables and simultaneous relationships affect the model. Therefore, only that a relationship exists can be established without making any further consideration about the reasons creating that relationship. Moreover, in analysing aggregated data of countries, individual behaviours are missed, making it more challenging to understand the real factors behind the relationships that usually respond to individual behaviours rather than aggregated factors.

6. OTHER CONSIDERATIONS

6.1. Return on investment

In the current environment of budget cuts and increasing social pressure towards assessing the benefits of public investments, performing careful evaluations of the costs and benefits associated with investments in educational technology has become increasingly important. The most commonly used methodology to evaluate public investment is cost-benefit analysis (EC, 2008). However, assessing the economical benefits of investments in educational technology is a challenging task due to a range of different factors (see Figure 49).

Figure 49: Challenges to cost-benefit analysis of using technology in education



Source: compiled by the authors based on (UNESCO, 2011)

It is usually very difficult to compare conventional teaching methods to those emerging from the use of technology. Technology can be used in very different ways from it being completely absent, to a fully pervasive on-line environment with no physical interaction among teachers and students, or blended learning where a mixed approach is followed. Moreover, technology can be used in a wide array of applications, such as collaborative creation of contents, on-line communication, e-learning and digital contents; therefore, including the all the benefits of using technology in a cost benefit analysis is impossible. The time frame is also a crucial factor to consider. Educational benefits do not transpire in the short-term. Most of the benefits appear in the medium-term, such as improved academic achievements or drop-off rate reduction, or many years after the policy is enacted, such as higher rates of university admission or increased lifetime earnings. Most of the benefits are difficult to capture, such as the increased satisfaction of being better educated; it is also difficult to isolate the causes (and therefore the costs) behind those benefits.

There are several ways to overcome these limitations when analysing the medium- and long-term impact of investments in education. Instead of just considering as a benefit the direct estimated cost savings, it is important to assess and quantify a wide array of other quantitative and qualitative benefits. As in most public policies, a cost-benefit analysis of public investment in education has to take into account non-financial benefits of policies and investments, such as positive and negative externalities. The impacts that normally have no market values are **called social return on investment (SROI)**, and its analysis focuses mainly on social and environmental effects of policies or programmes.

The Consortium for School Networking, the American professional association for district technology leaders that represent over 10 million K-12 students, has developed the value of investment (VoI) methodology to estimate the costs and expected benefits of technology projects. The methodology includes not only quantitative, but qualitative benefits supporting the mission of the schools to educate and maximize student potential. It helps district leaders evaluate the alternatives, analyse costs and benefits, and sell the projects to the society, while defining more sustainable initiatives (COSN, 2013).

The short-term benefits of technology in education are the cost-savings fostered by economies of scale —MOOCS are a good example, economies of educational materials — OER models, and the ability of teaching without requiring a dedicated physical infrastructure. There are other logistical benefits arising from higher flexibility in place, time and pace. The medium-term benefits are improved academic outcomes, higher levels of engagement and motivation, and supporting independent personalised learning. The long-term impacts affect individuals and the society as a whole: increased productivity and employability, higher earnings, and other intangible benefits of having a better educated population. The main costs are the total cost of ownership of the technological infrastructure, contents and services (initial investment and the on-going maintenance cost), and providing the right skills to teachers, families and education leaders. In the short-term, technology can impose an additional burden to teachers that need to change their teaching methods in the new environment. Moreover, the increased number of students that a teacher can theoretically manage in an on-line environment can substantially increase their workload, particularly if supporting technologies and methodologies, such as peer-to-peer assessment and virtual assistants, are not properly deployed.

In the specific case of on-line learning, it is expected to have higher fixed costs and lower variable costs in the virtual environment compared to the conventional teaching, and therefore the cost per capita of on-line teaching is reduced when the number of students surpasses a certain threshold.

6.2. Digital divide (the second one)

The digital divide between affluent and poor families in Europe is more than 40 points as shown in Figure 18 (Eurostat, 2014d). This divide at the household level is exacerbated by the divide at the school level. In fact, between 18-28 per cent of students depending on the grade, lack access to ICT both at home and at school, strongly hindering the digital confidence of students (Eurostat, 2014d). Even more challenging is the infrastructure divide turning into a knowledge divide. In highly developed countries, there is strong evidence (Krumsvik, 2008; Wood & Howley, 2011) that large-scale implementations in educational technology are fostering inequality in schools. In fact, evidence shows that the digital gap in advanced countries is widening and shifting from an access divide towards an divide in use (Bonfadelli, 2002). Therefore, policies focusing on achieving higher computer-to-student ratios in poor schools are inadequate, as the inequality emerges from the ability to properly use the technology (K.-K. Wei et al., 2011) - the so-called second digital divide (Attewell, 2001; Bonfadelli, 2002; van Deursen & van Dijk, 2011; K.-K. Wei et al., 2011).

Digital inequalities in advanced economies are arising as a result of huge investments in technology at schools (Krumsvik, 2008). Although the decreasing infrastructure gap, the use-gap – related to the outcomes of using the technology – is widening, both at the school and household levels (Judge et al., 2006). Technology benefits students of affluent families more than poor ones (Krumsvik, 2008) thus widening the digital gap between school districts (Mason & Dodds, 2005). Moreover, this fact is often concealed because investing in technology at poor schools, regardless of its real use, holds strong constituents' support.

This second digital divide at the school level can be more challenging that the achievement gap, and can substantially contribute to further increasing social and economic inequalities to a point difficult to reverse, affecting social mobility, people's income and their quality of life (Neuman & Celano, 2006).

The knowledge gap can also affect ICT growth and productivity (Becchetti & Adriani†, 2005; Vu, 2011), as future workers become digitally illiterate.

In the EU and other developed economies, the problem is exacerbated by the wide changes fostered by the Internet that can increase the social exclusion of low-income and disadvantaged students, thus leading to severe problems in their daily lives (van Deursen & van Dijk, 2011). Moreover, this problem will grow in the future due to the decreasing number of off-line alternatives to everyday tasks. The effect of knowledge inequalities in the Internet era cause greater problems than in the physical context (L. Wei & Hindman, 2011).

Digital inequalities are, at the same time, a cause and a consequence of socio-economic disparities and can deeply affect the current status and future achievements of students and their families. Conversely, by properly tackling the digital inequalities at the school level, the whole society can benefit by fostering efficient, fully digitalised societies.

6.3. Regulations and ethical issues

The use of technologies in education encounters various regulatory and, moreover, ethical issues. We have identified four main areas with legal and ethical implications that should be taken into account when deciding upon policy options and defining new policies and actions. These topics include: cyber security and privacy, intellectual property rights, standardisation and interoperability. It should be noticed that, in addition, the aforementioned reforms of the curriculum and assessments methodologies might also require some legislative modifications.

6.3.1. Cyber security and privacy

The increasing use of emerging technologies in education and within schools raises concerns about privacy and security issues. These issues particularly affect two technology trends: cloud computing and learning analytics. In addition, the increasing use of the Internet augments associated risks, such as cyberbullying or grooming.

The use of **cloud-based technologies** at schools might bring about risks derived from the protection of students' private data. By using cloud computing services, schools transfer a considerable amount of student information to third parties, sometimes even transferring the ownership of the data. These services are in many cases hosted abroad, within or outside of Europe, where regulations regarding security and data protection might differ from national regulations. In addition, agreements between service providers and authorities or schools often do not require the adequate levels of protection and are not adequately transparent (Reidenberg et al., 2013). These contracts must be clear regarding the security measures applied and the limits on the commercial use of data. Contracts must be transparent for all stakeholders, and parents must be appropriately informed of service terms and conditions. In sum, the key issues regarding the security of cloud services in education are: the ownership of the data; the regulatory compliance of services and location of the data; the technical and administrative protection measures of the service; and the transparency of agreements regarding the disclosure and uses of students' information.

The application of **data analytics to education** may bring many benefits but also important challenges to privacy and involve relevant ethical concerns. Slade and Prinsloo (2013) identify three main types of ethical issues regarding learning analytics: location and interpretation of data; informed consent, privacy and the de-identification of data; and classification and management of data.

Although there is no specific legal framework for learning analytics, existing regulations pertaining to data protection and privacy should be applied to learning analytics, including the Data Protection Directive (EC, 1995) and its upcoming reform (Sclater, 2014). This legal framework is based on three main principles: transparency, consent and fairness (proportionality), to which the reform aims at adding "privacy by design" and "privacy by default", while improving the control and accessibility of citizens to their own data and regulating the "right to be forgotten" (EC, 2012b).

However, experts suggest the need to develop a code of conduct for the application of data analytics to education, a very sensitive field (Sclater, 2014). Such a code would allow ethical principals guiding learning analytics in a rapidly changing technological environment to be contextualised in a flexible manner (Sclater, 2014).

Data protection policies and regulations should seek a balance between the protection of fundamental rights and promoting innovation and the development of European industries, effectively protecting citizens while minimising their potential negative impact on the development of learning analytics products and services.

Finally, the potential increase of risks inevitably linked to a higher frequency of Internet use**, such as cyberbullying or grooming,** should be considered when analysing security issues. For that reason, the increase of the use of the Internet for educational purposes and the implementation of strategies such as BYOD, may result in higher risks. The prevention of such risks relies on the empowerment of parents and teachers, the creation of a positive school environment and the involvement of service providers (EC, 2013e).

6.3.2. Property rights

As identified by the Opening Up Education initiative, one of the most relevant barriers to the development of digital educational resources in Europe is the lack of a clear and harmonized legal framework. The current European intellectual property regime hinders the creation and use of online educational contents and generates uncertainty for educators and learners (EC, 2013b). It is not only difficult for creators of new content to define the adequate protection of their work, but also the reutilization of existing content with educational purposes faces very important limitations. Cross-border consumption and management of copyrights is highly complex and the IPR regime obstructs the definition of innovative sustainability models (Feijoo et al., 2013).

6.3.3. Standardisation and interoperability

In our digital life, we use multiple devices, applications and contents that interact with each other. Further, we increasingly want to have control over the contents and services we use. To guarantee that all these elements work across borders, platforms and brands, common standards need to be implemented. The Digital Agenda for Europe acknowledges that interoperability and standardization would play a key role in rebooting "Europe's economy and help Europe's citizens and businesses to get the most out of digital technologies" (EC, 2010).

However, in practice, there is an important lack of interoperability between operating systems and platforms and lack of portability of resources that might be hindering full exploitation of the benefits of educational technologies. If applications do not run seamlessly through devices, and educational contents are unavailable across platforms, technology options for education are reduced and costs increase.

6.3.4. Platform openness (market dominance)

Mobile devices are nowadays dominated by two Operating Systems (OSs): Google's Android and Apple iOS, together accounting for over 90 per cent of the market in Europe, and reaching 95 per cent in some countries, such as Spain (kantarworldpanel, 2015). These companies set their own closed standards and difficult interoperability for commercial reasons. Services, contents and applications are developed for specific OSs and their closed nature makes it difficult for consumers to switch from one system to another without losing their data and access to the services they have already purchased. This market dominance reduces competition and restricts business opportunities for European service providers and developers (Telefónica, 2014).

Open standards and platforms allow all stakeholders participating in the ecosystem to better search for the common good (EC, 2013b).

6.4. Evaluation

We are moving towards a new challenging environment with plenty of exciting opportunities and hidden traps where we are learning by doing. Therefore, it is particularly important to not only continuously design and implement new policies, but to assess the results of these policies. It will allow building the path towards successful initiatives. However, there is a lack of rigorous evaluation of public policies in educational technology in Europe. Performing a query in Google Scholar about "technology education" and evaluation in US and Europe[14], we find that the US doubles the results of Europe. Evaluating policies can be particularly interesting in Europe where results of different policies deployed at the national and regional levels can be easily compared creating a natural policy lab that could substantially improve the effect of the policies in the medium-term.

However, it is important to point out that evaluation should not be focused on technology itself but on how technology is integrated into the educational process following a comprehensive approach where several factors, such as stakeholders' engagement, schools' profile, family environment, contents and application availability as well as curricula adaptation are taken into account. Moreover, the effect of educational policies should consider a wide variety of short-term performance indicators, such as academic achievements, attendance, disciplinary actions, attrition and inequalities in addition to long-term achievements, such as university attendance, lifelong earnings, social involvement and overall satisfaction. To address these challenges, creation of longitudinal datasets[15] with rich information about technology and the way technology is used is strongly advised. The lack of this data in the EU makes it difficult, if not impossible, to perform rigorous evaluations to isolate the casual relationship between educational technology and educational outcomes.

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[14] The queries were (1) *"technology education" AND evaluation AND Europe* that resulted in 19,900 results and (2) *"technology education" AND evaluation AND US* that resulted in 38,600 results. Both queries were performed at the same time on the 2nd of February 2015.

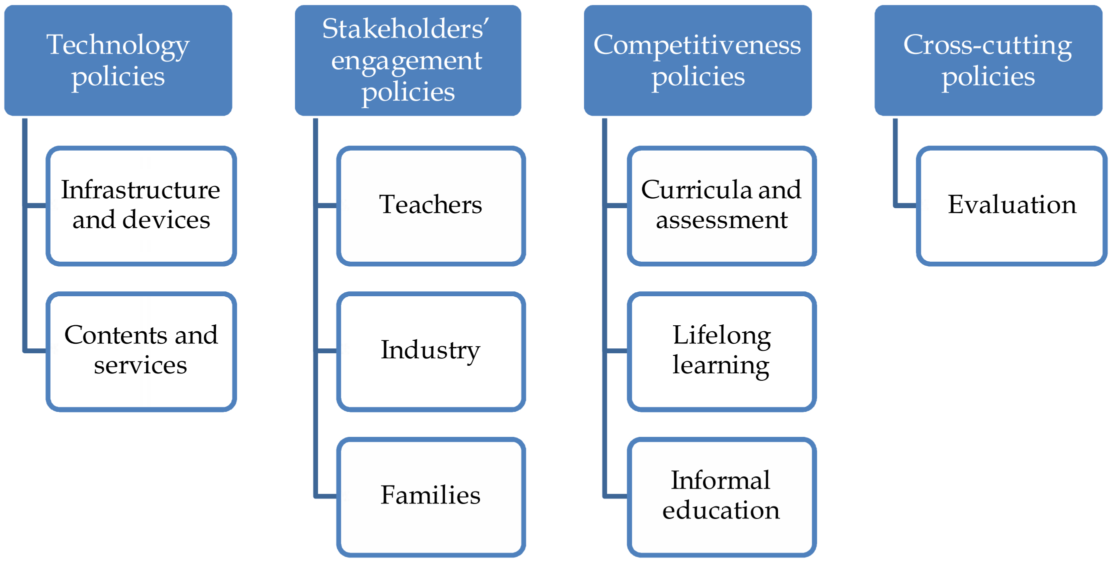
[15] Longitudinal datasets track a cohort of students at multiple points in time, making it possible to analyse the effect of current policies on further achievements.

7. POLICY OPTIONS

This chapter analyses different policy options related to educational technology that can contribute to addressing the challenges facing European society. The goal of the chapter is to present different policy options and analyse how adequately the different options address these main challenges. Based on the analysis, and taking into account further political and socio-economic considerations, policy-makers may select the policies that better fit the interest of the European society.

The different policy options are structured into four groups: technology policies, stakeholders' engagement policies, competitiveness policies and cross-cutting policies, as shown in Figure 50.

Figure 50: Groups of policy options



Source: compiled by the authors

Technology policies involve initiatives intended to evolve current technological education infrastructure, contents and services to draw upon emerging technology trends to better fit the challenges facing the educational system. Stakeholders' engagement policies refers to programs that can increase the involvement of key agents in the process of effectively deploying technological education in Europe, namely teachers and school leaders, families and the industry. Competitiveness policies seek to analyse different options to improve Europe's standing through the use of technology in education. Cross-cutting policies include ways to reduce uncertainty by creating tools to better evaluate the results of the policies. The different policy options are not mutually exclusive and in some cases, some policies reinforce each other.

The structure of the chapter is as follows:

1. Based on the findings of the analysis, the main challenges facing Europe are described.
2. Based on these challenges, a matrix of assessment criteria is constructed.
3. Different policy options are described and assessed using the aforementioned criteria.

7.1. Challenges

As described in the international benchmarking, Europe is lagging behind in education achievements compared to other countries, particularly Asian countries. Moreover, there seems to be a relationship in Europe — stronger than in other countries — between academic achievements and stagnant economic growth and increasing unemployment rates. Other advanced economies, such as the US and Canada, have similar educational performance and are performing much better in macro-economic indicators.

A similar pattern arises when considering the skills of adults. Educational technology is expected to substantially improve education performance by increasing the quality while reducing — or at least maintaining — the cost. However, there are several factors that challenge the effective deployment of educational technology in Europe, namely: (1) lack of compelling evidence of the benefits of the different technology options in education performance; (2) persistent inequalities among European countries and within the countries; (3) the increasing speed of the technological evolution; (4) the lack of strong involvement of the different stakeholders in the process including teachers, civil society and the industry; (5) inadequate regulatory framework; and (6) budget pressure. Some of these factors are strongly intertwined: regulation, misunderstanding the benefits, and lack of stakeholder engagement can hinder the effective deployment of emerging technologies. The delay in the deployment of these technologies can contribute to increasing inequalities. A lack of assessment regarding the benefits can further delay the overall process.

7.1.1. Lack of compelling evidence of the benefits of technology on education

Our analysis suggests there is a lack of strong evidence regarding the benefits of educational technology on education achievements. Higgins, Xiao, and Katsipataki (2012) found a consistent but small positive relationship between educational achievements and using technology in education by analysing research conducted over the last 40 years. Tamim et al. (2011) bring together 25 meta-analyses encompassing 1,055 primary studies along 40 years to find only a small to moderate positive effect on using technology over traditional teaching. (Means, Toyama, Murphy, Bakia, and Jones (2009)) carried out a meta-analysis of 50 studies comparing educational performance of online to face-to-face classes from 1996 through 2008 to find that students in online training performed modestly better than those receiving face-to-face instruction, and that the positive effects were more likely related to methodological issues than to the media itself. Based on these results, the conclusion is that there are no magical formulas to effectively integrate technology into education.

In fact, in our analysis, we discovered an inverted u-shape relationship between the level of use and educational achievements. It suggests that neither the level of technology penetration nor the level of use have a direct effect on education performance. Education achievements tend to be smaller for lower levels of use, better for moderate levels of use, and they worsen again for higher levels of use. These findings were also found by (Fuchs & Wößmann, 2004) by analysing micro-data of the PISA dataset. It seems that success will be achieved through a thoughtful reflection on the best use of technology rather than by extensive deployments of technology at schools.

7.1.2. Persistent inequalities

Although the situation has substantially improved over the last years, disparities still persist among and within European countries, both in terms of technology penetration and use at schools and at home (EC, 2014a). Moreover, once the digital divide at the infrastructure level is bridged, a more challenging digital divide arises, namely the inability of low income and computer illiterate populations to draw upon technology to increase their welfare. Technology use seems to increase the gap between poor and affluent people instead of reducing it.

7.1.3. Increasing speed of the technological evolution

The education system cannot keep up with the rapid evolution of technology. Most of the computers at schools are fixed, while the market share of mobile devices substantially outpaces that of fixed computers. Effectively integrating advanced and promising technologies, such as cloud computing or data analytics in the educational system, becomes a challenging task. Budget cuts further exacerbate the problem, causing the educational system to lag behind technology evolution.

7.1.4. Low involvement of the different stakeholders

There are several groups behind educational technology: teachers, principals, students, policy-makers, families, civil society and companies. Although it is likely they all share an interest in ensuring the proper use of technology to improve education performance, different short-term interests make it difficult to align the different stakeholders towards a common goal. Policies should be defined to draw upon each other's strengths. However, policy makers and public servants usually act independently and in isolation without taking into account the limitations, beliefs, interests and strengths of the involved groups. Public consultations try to avoid this problem. Although they allow the participation of the different stakeholders, it is unclear whether public consultations are inclusive, transparent and truly capture the interests of the parties (Quittkat, 2011).

7.1.5. Inadequate regulatory framework

The Internet ecosystem and its global stakeholders, based on global rules that usually fall out of the scope of national regulations, represent a challenge for governments that are incapable of establishing frameworks to promote a right, fair, and secure growth of new services. Internet users – and policy makers - are challenged by privacy, security and interoperability issues, which can be particularly relevant for the educational system, thus hindering the effective and secure deployment of educational technology services.

7.1.6. Budget pressure

In 2011 and 2012, due to the effect of the economic crisis on budget deficits, up to 20 European countries/regions cut their education budgets, 10 of them[16] experienced cuts higher than 5 per cent. Conversely, 9 countries/regions increased their education budget between 1 per cent and 5 per cent and 4[17] experienced an increased higher than 5 per cent in real terms. Although the situation is likely to improve over the next years, further cuts are expected in several countries, such as Portugal, the UK (Wales), the Czech Republic and Slovakia. These cuts have affected funding allocated to the development of ICT policies (Eurydice, 2013a).

7.2. Assessment criteria

To properly assess the different policy options so policy-makers can select the best alternatives in their specific contexts, a multi-goal assessment analysis is performed. The analysis is carried out by using an assessment criteria matrix. The criteria selected are based on the challenges described above:

1. **Managing uncertainty**: how well the policy option manages the uncertainty related to the benefits of specific technologies on educational outcomes, so it can better contribute to improving the competitiveness of European citizens.

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[16] Greece, Italy, Cyprus, Latvia, Lithuania, Hungary, Portugal, Romania, the UK (Wales) and Croatia.

[17] German community of Belgium, Luxembourg, Malta, and Turkey.

2. **Tackling inequality**: how the policy option contributes to reducing inequalities, both in terms of infrastructure and use, and at the school and household level.
3. **Innovative approach**: whether the policy benefits from recent trends in technology and can foster further innovation.
4. **Stakeholder engagement**: whether the policy has been designed taking into account the interests, beliefs and limitations of the stakeholders and therefore contributes to the strong involvement of the different interest groups.
5. **Regulatory concerns**: whether the policy faces challenges regarding regulatory issues, such as privacy, security, copyrights, lack of standardisation, etc.
6. **Budgetary feasibility**: whether the policy is efficient and can fit into the current environment of budget cuts.

Additional criteria are included in the analysis:

7. **Political feasibility**: whether the policy is likely to be backed by political support. It includes balancing the mandate-term vision of politicians with long-term policy vision.
8. **Feasibility in the EU context**: whether the policy can be easily implemented in the current European framework.

The different policy options are assessed against each of these criteria by using a three-level scale: low, medium or high. A low value means that the policy option does not adequately meet the objectives defined for each criterion.

7.3. Technology-related policies

The different options included in the analysis do not focus on proposing specific technologies or projects. There are many and varied technologies while every region and country face specific challenges and have specific contextual factors. Moreover, the education system is very wide and no technology will be adequate to solve all problems. Making very concrete technology recommendations at the European level for the entire education system would be quite daring and would likely yield inadequate conclusions.

Therefore, the different policy options are intended as strategic approaches that provide a framework for policy-makers to define more concrete policies depending on contextual factors.

7.3.1. Extensive deployments of technology at the school level

Although the level of technology available at schools has substantially improved since the year 2000 (Eurydice, 2011, p. 75), there are still important gaps that are fostering policies towards the fast deployment of new technology infrastructures at schools. In most European countries, assuring a sufficient number of computers per students or full broadband connectivity is the goal of policy-makers (Eurydice, 2011, p. 73).

The implementation of programs aimed at the extensive deployment of technologies in schools contributes to reducing the digital divide between schools at the infrastructure level while achieving ratios of technology penetration close to saturation (1 computer per student, 100 per cent of schools with broadband connectivity, or 1 projector per classroom). Moreover, constituents are likely to support these policies because parents believe that enrolling their children in fully equipped schools will improve the quality of their education.

However, there are concerns about the true effectiveness of these programs due to a lack of evidence linking the level of infrastructure to technology use and educational performance. Experiences about 1to1 initiatives that do not drive the expected results (Holcomb, 2009) or the provision of computers to low-income children worsening their academic performance (Vigdor & Ladd, 2010) raises concerns about these projects. High-scale deployment projects should be carried out when compelling evidence of the results exists to avoid spending large amounts of public money without obtaining clear benefits.

In addition, extensive deployments of ICT infrastructure at the school level may hinder the effective integration of technology on the day-to-day activities of teachers and can impose a burden on the technical capability of the schools. Moreover, costly technical maintenance can further challenge public budgets.

As a result, these policies should take into account the following factors: high public spending, closing the digital gap among and within schools, having strong public support, and a lack of evidence about their real effectiveness.

The result of the assessment of this policy approach is shown in Table 2.

Table 2: Assessment matrix for the "Extensive deployments of technology at the school level" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	Low	This approach will not help to address uncertainty and usually lacks the comprehensive approach required to create innovative learning environments.
Tackling inequality	Medium	This approach will reduce the inequality in infrastructure at the school level, however, it will likely foster more challenging inequalities due to the manner in which the technology is used.
Innovative approach	Medium	This approach can foster innovation at the technology level, however, it is unclear if it will support pedagogical innovation.
Stakeholder engagement	Low	Usually, extensive deployments of technology at schools do not have the support of teachers and school leaders, who lack the skills to integrate the technology into the educational process.
Regulatory feasibility	Low	This approach does not specifically consider regulatory issues, although regulatory problems can arise subsequent to the deployment.
Budget feasibility	Low	Extensive projects are very expensive and impose a considerable burden on public budgets; also, it is unclear if the benefits outweigh the costs.
Political feasibility	High	Large initiatives have high media visibility and social impact and are normally highly appreciated by policy-makers
Feasibility in the European context	High	Large scale projects are usually attractive to national and regional governments.

7.3.2. Pilot based deployment

The uncertainty associated with the deployment of technology in education suggests that policies should be implemented cautiously.

Policy-makers may design a pilot-based approach to boost innovation among early adopters of emerging educational technology. In this approach, small-scale pilot projects are implemented, assessed and replicated when there is evidence that supports their feasibility and benefits. In this way, the deployment of initiatives at a lower scale, although delaying the process in the short-term, may yield better medium-term outcomes and promote innovation.

Europe provides a natural laboratory to test different initiatives in an orderly and fast manner. Detecting and properly assessing national and regional initiatives can provide very useful insights for other environments to deploy technology projects that are more likely to improve educational performance. Moreover, the EU can play an important role in supporting national or regional governments to draw upon insights from sharing evidence among countries and from evidence based research (Schlotter et al., 2008, p. 19) when defining specific policies. European Schoolnet (Schoolnet, 2014b) is currently making some pilots, such as the iTEC (Innovative Technologies for Engaging Classrooms, 2010-2014) project (Schoolnet, 2014c) where educational tools were piloted in over 2,500 classrooms across 19 European countries with funding of 9.45 million Euros (0.018 euro per capita), and the Creative Classrooms Lab (CCL) project (Schoolnet, 2014a), which aims to assess innovative teaching and learning methods by using tablets in and out of school. These pilots could be deployed on a much larger scale with strong participation of education stakeholders, the industry and researchers. The EU can offer categorical grants[18] to European schools and universities willing to participate in pilot projects, provide technical support to the selected schools, and carefully assess and disseminate the results. A good example is the Idaho Technology Pilot Project where the 2014 Idaho Legislature appropriated 3 million US dollars (1.8 US dollar per capita, about 100 times higher than the iTEC project) for pilot projects in schools to improve academic growth and financial efficiencies through the adoption of the full integration technology model (IDAHO, 2014).

This is particularly relevant when considering high-risk and highly innovative projects. The result of the assessment of this policy approach is shown in Table 3.

Table 3: Assessment matrix for the "Pilot based deployment " policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	High	This approach will help to address uncertainty and will likely yield better (or at least more efficient) results in the medium-term.
Tackling inequality	Medium	Although this approach does not reduce inequality, it can drive to more effective inequality-driven policies.
Innovative approach	Medium	This approach is conservative in the sense that more innovative approaches are considered carefully. However, it can foster further innovation because of the creation of natural laboratories where assessing innovative approaches is feasible.
Stakeholder engagement	Medium	Focusing on adapting successful policies to the specificities of the context can lead to higher levels of stakeholder engagement.
Regulatory feasibility	Medium	Although this approach does not specifically consider regulatory issues, it will uncover regulatory issues that can be addressed prior to full deployment.
Budget feasibility	High	One of the main benefits of this approach is its ability to substantially reduce public investments in large projects with unexpected outcomes.

[18] Categorical grants are grants provided for a specific type of spending.

Political feasibility	Low	Politicians tend to like initiatives with short-term impact and high media visibility (Schlotter et al., 2008, p. 18).
Feasibility in the European context	Medium	This approach can benefit from the extensive range of initiatives within the EU that can act as a natural laboratory.

7.3.3. Defining and reaching a minimum threshold infrastructure at schools

Inequalities in the level of technology at schools still exist in Europe. Although the problem has substantially diminished over the last years, a gap still exists both between and within countries (Eurydice, 2011). In 2012 , Greece had 21 computers per student in grade 8 in comparison to 2 computers per student in Sweden; further, more than 20 per cent of schools in Italy did not have broadband connectivity compared to 0 per cent in Finland (E. Schoolnet & Liege, 2013).

One way to avoid massive infrastructure deployments at schools is to provide a sufficient level of school technology complemented with shared centralized services.

An ultra high-speed Internet connection, a school local area network and a sufficient number of school computers are the core elements of this infrastructure. Additional elements, such as projectors, interactive whiteboards and printers, are advised.

The main complexity of this model is to define the optimum level of infrastructure that will depend on contextual factors, such as local teacher involvement, technical capabilities in the school and connectivity availability. The EU can define a minimum and optimum level of technology infrastructure by using previous research undertaken by European Schoolnet, experts and other stakeholders. Once the threshold is defined, the EU can provide categorical grants[19] and technical support to Member States depending on the number of schools under the minimum level.

This option is likely to be more cost-efficient that the massive deployment of full ICT infrastructures at the school level, while yielding good results if complemented with providing shared centralised services. However, concerns regarding privacy and security issues might arise that should be appropriately addressed from the beginning. In addition, the idea of centralising infrastructures and services might face political and administrative barriers in countries with highly decentralised systems, as well as resistance by public employees responsible of ICT services. Politicians, managers and the public may not support this option, as they often consider more to be better.

The result of the assessment of this policy approach is shown in Table 4.

Table 4: Assessment matrix for the "Defining and reaching a minimum threshold infrastructure at schools" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	High	This approach will help to address uncertainty by promoting a flexible framework.
Tackling inequality	Medium	A minimum level of infrastructure and services will be provided to all the schools. It will further reduce inequalities if complemented with other policies.

[19] Categorical grants are grants provided for a specific type of spending.

Innovative approach	Medium	This approach is conservative in the sense that only the basic infrastructure will be provided. However, it can foster further innovation if complemented with other policies.
Stakeholder engagement	Low	The public and school leaders can oppose the policy (more is better).
Regulatory feasibility	Medium	This approach does not specifically consider regulatory issues.
Budget feasibility	High	One of the main benefits of this approach is its ability to substantially reduce public investments in large projects with unexpected outcomes.
Political feasibility	Low	Politicians may be afraid of a lack of public support (low media impact of these policies) and bureaucrats reluctance to centralise services.
Feasibility in the European context	Medium	Highly decentralised countries in Europe might be less enthusiastic about these type of policies, since they require certain levels of centralisation.

7.3.4. Sharing infrastructure and services in the cloud

Promoting cloud models in the educational environment provides several benefits and allows for the implementation of shared services and infrastructures. It increases flexibility and the quality of the services, reduces local maintenance, promotes innovation, provides updated services, reduces the time of deployment and reduces costs. Moreover, if services are shared across the entire educational system, it enables the same level of services to be provided to all schools, thus reducing inequalities. New, innovative and reliable services can be made available to schools efficiently and conveniently, without the hassle of deploying complex on-site infrastructures.

However, this approach can only be effectively implemented if all educational centres have a minimum infrastructure, particularly fast or ultra-fast Internet access.

In this model, on-site school infrastructures are kept to a minimum in order to connect the devices to the cloud services; also, services are provided in a centralised manner, as education agencies are equipped with the required resources and knowledge to deploy the services.

By keeping the school infrastructure to a minimum, further updating of the educational technology infrastructure requires lower investments, and the educational environment can more easily benefit from the fast technological evolution. It also provides the basis for emerging services, such as data analytics, that requires information to be easily available.

A deeper collaboration of the private sector is advised by using public-private partnership (PPP) models that can draw upon the extensive expertise of private technology companies to deploy innovative models, while sharing the risks and keeping the costs to a minimum.

This model calls for all the schools to have ultra-high speed Internet connection (more than 100 Mbps). It will require updating current connectivity at schools. However, it can be difficult to provide such speeds to rural schools. It is likely that the fast evolution of wireless and satellite technologies will contribute to tackling this problem. Security, privacy and standardisation concerns can also hinder the deployment of these models.

An example of this policy is the EU funded project, Europeana Cloud (Europeana, 2014a) (2013-2016), coordinated by the European Library to create a shared cloud infrastructure for European cultural heritage content. It will allow users to store and share cultural digitalised objects while establishing a clear legal framework to facilitate reutilisation. It helps to reduce costs thanks to greater efficiency in the management of both IT infrastructure and data, and provides a rich set of contents and service that can be easily used by teachers and students.

The result of the assessment of this policy approach is shown in Table 5.

Table 5: Assessment matrix for the "Sharing infrastructure and services" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	High	This approach will help to address uncertainty by providing much higher flexibility at the infrastructure level.
Tackling inequality	High	This approach can contribute to reducing inequality, both within the school and among schools, as the services are provided to all users, regardless of their location. However, it is important to guarantee that all schools have the required high-speed connectivity to access the shared central services.
Innovative approach	High	This approach can foster innovation because of its higher flexibility, particularly if accompanied by a stronger involvement of the industry in providing the shared platforms and services.
Stakeholder engagement	High	Reducing the infrastructure at the school level will have the support of teachers and principals. The industry is expected to strongly support the approach, particularly if deployed by using PPP agreements.
Regulatory feasibility	Low	Privacy and standardisation issues can hinder the effective deployment of the policy.
Budget feasibility	High	One of the main benefits of this approach is its ability to substantially reduce public investments in technological infrastructure.
Political feasibility	High	It is unclear whether politicians will support the approach. It will likely depend on the stakeholders' standing. School principals and large ICT companies can support the idea. Small companies can oppose cloud services because they are unable to compete with big companies to provide those services. End users may be concerned about security and privacy issues.
Feasibility in the European context	High	The EU can promote regulatory harmonisation regarding standardisation and privacy issues. Moreover, some central services or contents can be provided at the European level that can be used by individuals and Member States' educational institutions.

7.3.5. Drawing upon students' devices

Students' devices are an untapped resource that can contribute to increasing the number of devices available at schools with minimum impact on public budgets. By using these devices, 1to1 models can be deployed in a flexible, effective and straightforward way in the so-called BYOD model.

However there are some caveats concerning this model. Low-income families can lack the resources to buy mobile devices for their children; consequently, the policy may foster further inequalities. This policy should be accompanied by providing devices to students from low-income families. There are several ways to do so, such as direct delivery by the schools – even in borrow or rental models - or providing vouchers to low-income students. It can further contribute to reducing the digital gap if students and families of low income households are properly trained to effectively use technology at home.

Another consideration is the lack of standardisation of digital contents and services to run on the different platforms of the students' devices. Accordingly, this policy needs to be backed up by fostering a regulatory framework to guarantee the interoperability of educational contents among the different commercial platforms. Privacy issues are another concern, as personal information about the students can leak into the educational network.

It would also contribute to alleviating the problem of technology obsolescence at schools, as the rapid updating of devices will be the responsibility of students.

The result of the assessment of this policy approach is shown in Table 6.

Table 6: Assessment matrix for the "Drawing upon students' devices" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	High	This approach will help to address uncertainty by integrating a flexible device already in the hands of students.
Tackling inequality	Medium	This approach can reduce inequalities if backed by policies to provide equipment and training to disadvantaged students.
Innovative approach	High	This approach will draw upon the innovation naturally promoted by the evolving market of mobile devices. However, it is important that technological innovation also yields pedagogical innovation.
Stakeholder engagement	Medium	Teachers may be reluctant to use students' devices in class. Industry and families can support the idea.
Regulatory feasibility	Medium	Privacy and standardisation issues can hinder the effective deployment of the policy.
Budget feasibility	High	One of the main benefits of this approach is its ability to substantially reduce public investments by using students' devices.
Political feasibility	Medium	The initiative is likely to have high media visibility. However, the initiative should be designed to prevent inequality and privacy issues to count on public support.
Feasibility in the European context	High	The high penetration of smart devices in Europe would facilitate the implementation of these types of policies.

7.3.6. Drawing upon open and collaborative environments to create educational resources

The Internet promotes an environment of open collaborative creation. Contents and services can be developed by the community (teachers and students) and can be shared with other users for both formal and informal learning. Content and services can be further improved and adapted to better fit specific needs by other users. The OER movement analysed in chapter 2.3.1.1 is the most representative sample of this trend. This movement is very promising and, if properly managed, can make an enormous number of digital educational resources available to the community.

However, there are some caveats that deserve consideration. Property rights should be clearly established in order to take full advantage of the model. It is expected than only a low percentage of teachers and students are able to deploy high quality digital contents. In fact, a lack of quality digital contents and the difficulty in finding the contents can hinder teachers and students from being able to effectively integrate the open contents into the education process. The Open Education Europe project has a search page to look for educational resources (EU, 2014a). However, it is unclear whether the contents have been deeply assessed and whether teachers and students are able to easily find the resources for which they are searching.[20] Therefore, the European Commission could assure contents' quality and provide tools and training to facilitate obtaining to the right contents. A lack of standardisation is another factor that can hinder its use. Moreover, the contents usually need to be adapted to local specificities, such as language — rapid advances in automatic translation may help to solve this issue — and other socio-cultural issues. Policy makers should define policies to tackle these problems to foster a truly collaborative environment. However, the variety of challenges makes these policies complex and therefore a comprehensive approach involving regulatory, technical, training, and cultural issues is advised. For instance, the Forward Project of the Europeana Foundation (Europeana, 2014b) aims at creating a European system to disseminate the intellectual property right status of audio-visual works. This service will allow users across Europe to clarify the copyrights of a work, including orphan works, in order to re-use it. It will consider national legislations and the Directive 2012/28/EU on Orphan Works.

Another consideration is the role of the different stakeholders. While the education sector may be in favour of these models, it is likely that the industry of contents may oppose them. Finding ways in which commercial and open contents can co-exist has the potential to benefit the education sector.

Another factor to consider is to establish policies to assess the impact of these contents on integrating technology into the education environment and whether it affects educational outcomes.

The result of the assessment of this policy approach is shown in Table 7.

Table 7: Assessment matrix for the "Drawing upon open and collaborative environments to create educational resources" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	Medium	It is still unclear whether educational resources created through collaborative environments are contributing to improving the educational system.
Tackling inequality	High	Although this approach can promote the availability of free, high quality contents, it can also increase the gap between teachers who are able and unable to use the technology to develop and use contents.
Innovative approach	High	It can foster pedagogical innovation by drawing upon the knowledge and expertise of teachers and students to develop contents designed to fit their specific needs.
Stakeholder engagement	Medium	Although the education sector (and the public) may be in favour of these models, it is likely that the industry of digital contents may oppose them.

[20] A total of 505 out of 1237 resources are unclassified (page visited on 12th of February 2014).

Regulatory feasibility	Medium	Property rights and standardisation issues can hinder the effective deployment of the policy.
Budget feasibility	High	One of the benefits of this approach is its ability to reduce public investments in the acquisition of digital contents.
Political feasibility	Medium	These initiatives tend to have strong support from civil society but might face opposition from the industry.
Feasibility in the European context	High	This approach can benefit from the large number of OER initiatives already in place within the EU. The EU can further support governments by promoting regulatory harmonisation regarding standardisation and property rights, providing advice about how to use the contents, supporting regional and national governments to adapt the contents to their local specificities, assessing the results and sharing good practices.

7.4. Stakeholders' engagement policies

7.4.1. Teachers

Although the role of teachers is expected to significantly evolve over the next few years due to the increasing effect of ICT on pedagogical practices (L. Johnson et al., 2014, p. 3), the truth is that teachers in Europe are not fostering new ways of learning and teaching (E. Schoolnet & Liege, 2013, p. 3); further, less than 25 per cent of students are taught by digitally confident and supportive teachers (EC, 2013c, p. 2). In fact, one of the main factors hindering the effective use of educational technology is the lack of ICT skills (L. Johnson et al., 2014, p. 22) of teachers and teacher's attitudes, abilities and experience (Pierson, 2001).

Therefore, it is important to reinforce teachers' ICT abilities, capabilities and knowledge. Various policy options can assist in this regard:

7.4.1.1 Reforming educators' training and assessment systems

Teachers can obtain the required skills and confidence by receiving training in initial teacher education and by further acquiring the skills through formal and informal lifelong learning. Admission to teacher education should include interviews and admission tests to assess that the new teachers have the right motivation, skills and attitudes to succeed in the network environment. These methods are only applied in a third of European countries (Eurydice, 2013b, p. 31). Initial teacher education should include subjects regarding pedagogical use of technology and skills to promote educational research, as a way for teachers to attain the foundations of educational technology while having the tools to further evolve their teaching practices to incorporate successful trends based on evidence.

7.4.1.2 Implementing specific Continuing Professional Development (CPD) plans

Educational organizations in Europe should promote Continuing Professional Development (CPD) plans to assure that teachers are able to adapt their teaching practices to the changing needs fostered by technology. This can be achieved by aligning CPD activities to promotion and salary increases while providing free activities and financial support to cover training costs (Eurydice, 2013b). However, only France, Lithuania, Romania and Slovenia require teachers to take part in CPD activities for salary increases and further promotion, while only 10 countries provide financial support for teachers to obtain CPD qualifications (EC, 2013f, pp. 33-34). Formal appraisal and receiving relevant feedback can also contribute to improve teachers' skills and personalising their CPDs.

7.4.1.3 Promoting collaborative transnational educators' communities

Eventually, the Internet supports collaborative and continuous professional development. Creating national and transnational teachers' communities where teachers can share concerns, knowledge, best practices and tips can contribute to increasing their confidence and acquiring new skills.

The result of the assessment of policies to engage teachers is shown in Table 8.

Table 8: Assessment matrix the "Teachers engagement" policies

Criteria	*Adequacy*	*Argument*
Managing uncertainty	High	This approach will help to address uncertainty by offering teachers the skills to effectively integrate technology into the education process.
Tackling inequality	Medium	These policies will help to reduce the gap among teachers, thus contributing to decreasing the gap among and within the schools, as high-poverty schools usually suffer higher levels of attrition (Darling-Hammond, 2003).
Innovative approach	High	This approach will not foster innovation in technology but will promote better ways of using educational technology, and therefore will contribute to pedagogical innovation.
Stakeholder engagement	High	Teachers' involvement and commitment will be much higher.
Regulatory feasibility	Medium	The first two policies require adapting regulations to change initial training and to align teacher ICT skills and professional promotion. The third policy may raise concerns about property rights.
Budget feasibility	High	The impact on public budgets is likely to be moderate in the short-term.
Political feasibility	High	Supporting teachers is likely to have strong constituency support.
Feasibility in the European context	Medium	The EU can support governments by promoting regulatory harmonisation regarding teachers' CPD, providing advice about how to adapt initial teacher education, assessing the results, and by sharing good practices.

7.4.2. Industry

The industry and the educational system have a two-way relationship. The industry is both a provider and a client. Education benefits from products and services produced by the industry, such as computers, Internet connectivity, software and contents. Companies benefit from citizens having better skills to respond to the increasing demand of a global technology environment thanks to formal and informal education. Enterprises are also providers of education, particularly on-the-job training. Enterprises have successfully integrated technology into their business processes and therefore have relevant expertise. New key players, such as Google, Apple and Amazon, have emerged from technology. More traditional sectors, such as banking, manufacturing, and retailing are also extensively using technology. On the other hand, education is not keeping up with integrating technology into their core activities. The education environment could draw upon the extensive experience of enterprises, particularly technology enterprises, to improve and accelerate the effective integration of educational technology. However, the first forum promoting co-operation with external partners was not organised by the European Commission until 2010[21] (Eurydice, 2011).

The effective integration of technologies in education should be undertaken in strong cooperation with the industry, taking into consideration the dimensions mentioned: as providers, as trainers and as employers. Cooperation does not need to be limited to the provision of products and services; moreover, this cooperation can be extended to more core activities, such as jointly defining the curricula and the assessment methods, or even participating in the policy-making process to better align the needs and goals of the industry and the educational system (Eurydice, 2011, pp. 86-87).

Nevertheless, potential opportunistic behaviours of the industry should be carefully taken into account when defining these types of policies.

Some of the possible policies to be implemented include:

7.4.2.1 Promoting Public-Private Partnerships (PPP)

Stronger and more effective collaboration can be established by promoting PPP between businesses and education agencies through collaborative, organizational and contractual means where both parties share goals and risks. There are several areas where this collaboration can be enhanced, such as: providing technology (devices, networks, connectivity, data centres), providing contents and services, providing maintenance and support, training the education community, helping to raise awareness among stakeholders, and offering advice to stakeholders engaged in the policy making process.

PPP may be classified into 2 different groups: contractual PPP and non contractual or collaborative PPP (Bovaird, 2004; Smitha & Sangita, 2008). Contractual PPP involves those projects in which an existing asset is transferred to the private partner or a new asset is built by the private agent to carry out a service. Risks are shared by public and private partners. Service fees are paid to the private partner. Public bodies usually pay for the service although it can be paid by the end users through user fees. Non contractual PPP relates to collaborative initiatives among public, private and NGO partners who share goals and mission in a joint effort. Current budget cuts and increasing technology investments in schools encourage PPP contractual agreements. This was the case in the developing world, where governments and development agencies lack the required funding, thus making private funding essential to deploy the services (Hosman & Fife, 2008); this is now also taking place in advanced economies such as the EU.

In the EU, PPP has been widely used in its contractual form, specifically with regards to developing complex infrastructure projects, but not in educational technology. Collaborative PPP experience is scarce in the EU compared to contractual PPP.

Some caveats should be taking into account when using PPP in technology projects due to the following: (1) rapid changes in technology; (2) low initial costs and high continuing costs; (3) high failure rate; and (4) complexity of risk transfer to the private sector (Yescombe, 2007, p. 27). The intangibility of ICT assets compounds the problem. However, the following benefits arising from the private sector offset those problems: (1) capacity for innovation; (2) extensive experience on implementing complex ICT projects; (3) skills and knowledge; and (4) financial support.

In summary, despite companies' interest, different issues are severely limiting the potential of PPP in technological projects at schools including: (1) government capacity; (2) concerns regarding use of PPP in ICT; (3) lack of assessment of current initiatives; (4) lack of a comprehensive approach; (5) projects' dispersion; and (6) weak integration with current policies.

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[21] The first school-business forum was held in Brussels during 24-25 March 2010.

7.4.2.2 Involving the industry in the policy-making process to better align its needs and education

A further extension of shortening the relationships between the government and companies is to involve more closely the industry in the policy-making process to better align the needs of the industry and the education system. The process may be challenging as some sectors may be opposed to the idea, believing that the vested interests of the industry would negatively affect the education process. However, high unemployment rates in Europe, particularly among youth, and an absence of large innovative companies in Europe, such as Google, Amazon or Apple, suggest that, apart from other factors such as a lack of entrepreneurship and investment culture, regulatory constraints and aversion to risk, something is failing in the education system that is not producing citizens with the right skills to succeed in the new global and fast evolving environment. There are several fields where this cooperation can be particularly relevant, such as redefining the curricula and the assessment methods, and strengthening the links between research departments and the industry.

There are some experiences of cooperation in Europe between public and private bodies to jointly define technological education policies, such as the Irish Joint Steering Group and the Norwegian Centre for ICT in Education (Eurydice, 2011, p. 87).

7.4.2.3 Strengthening cooperation in innovation and research

Another field of common interest is promoting research and innovation in educational technology. Over the past 5 years, there has been an estimated inflow of 6 billion US dollars of venture capital on e-learning projects. The worldwide e-learning market in 2016 is expected to reach 51.5 billion US dollars with an annual growth rate of 7.9 per cent (more than 16 per cent in Asian countries compared to 6 per cent in Western Europe). Western Europe is the second largest market after North America but it is expected to be overtaken by Asia by 2016 (Docebo, 2014). Both formal and informal education at all levels can benefit from the innovation in the sector, however, Europe seems to be lagging behind. Effectively including e-learning tools in schools can improve education achievements while helping students to incorporate technology into their lifelong training. The European Commission can support research activities in educational technology and stronger cooperation between universities and businesses in this field. For instance, the EU could create a specific area of educational technology in the framework programmes for research and innovation. In the current Horizon2020 program that area does not exist (EC, 2015).

7.4.2.4 Boosting the industry of educational contents and services

Digitisation is radically transforming the media and content industry; in many cases, the industry has been unable to adapt to the new features of the digital media environment. This is particularly relevant for the educational contents industry where traditional publishers in Europe are having problems migrating their current book offering to a new proposal of goods and services in the digital environment; moreover, the European digital content industry is fragmented and weak in comparison to the American industry (Feijoo et al., 2013, p. 143). This is the case not only regarding the contents itself, but also with regards to new services, such as e-learning or mLearning providers.

Governments can support the industry by improving the regulatory framework to protect intellectual property rights, promoting transnational use of contents — creating a European licensing agreement, fostering entrepreneurship in the sector, and providing funding for innovative projects in the educational arena (Feijoo et al., 2013). The implementation of a comprehensive set of policies to support this European industry would foster innovation and the development of new business models. The policies should include, at the very least, measures to: (1) improve the intellectual property regime to foster innovation; (2) promote the transnational creation[22], reuse, and use of contents by harmonising the European market, providing information about property rights, and reducing administrative burdens; (3) improve access to funding for innovative projects (particularly for SMEs and risk finance); (4) encourage entrepreneurship in the sector; and (5) promote an adequately skilled workforce for the sector (increasing science, technology, engineering and mathematics (STEM) studies, improving coding skills, etc.). For instance, following the example of the Copyright Hub initiative (TheCopyrightHub, 2014)[23], the EU could foster reusing contents of third parties to develop new contents by clarifying the property rights associated with current contents.

These policies could complement the development of open education resources; creating such resources would not necessarily be contradictory to developing a strong and competitive industry. Mutual benefit can adopt various forms. The industry can provide open contents that can be further improved by the users. The government and the industry can provide platforms hosting commercial and open resources where the education sector can easily find and access contents and services. The industry can use open contents as a basis to develop new services at a lower cost.

The result of the assessment of policies to engage the industry is shown in Table 9.

Table 9: Assessment matrix for the "Industry engagement" policies

Criteria	*Adequacy*	*Argument*
Managing uncertainty	High	This approach will help to address uncertainty by sharing risks with the private sector. Creating a competitive environment of providers of digital contents can contribute to having a wide range of different innovative products and services that can help to find the options that best suit the needs of teachers and students.
Tackling inequality	Medium	This approach does not contribute to reducing or increasing inequality.
Innovative approach	High	This approach will draw upon the innovation naturally promoted by the rapidly evolving technological industry. However, it is important that technological innovation will also yield pedagogical innovation.
Stakeholder engagement	High	It is expected that there will be strong industry support. However, bureaucrats and public officials can be reluctant to encourage stronger involvement of the private sector within the public service.
Regulatory feasibility	Medium	Some regulatory issues regarding public procurement should be considered. These policies might require harmonisation and revision of IPR regimes in most European countries.

[22] Different languages among European countries can challenge the creation of transnational contents. However, the experts interviewed think that this problem may be easily overcome by providing common contents in English that are further translated into other languages.

[23] The Copyright Hub is a website launched by a UK non-profit company, The Copyright Hub Ltd, promoted by the creative industry. It aims at becoming a single access point to copyright information and simpler licensing, reducing transactions costs thanks to its connections with other websites. Its mission is to "help copyright work the way the internet works, making the process of getting and giving permission quicker and easier for everyone".

Budget feasibility	High	One of the main benefits of this approach is its ability to reduce initial public investments in large projects with unexpected outcomes and ensure the risks are shared with the private sector.
Political feasibility	Medium	Politicians may be afraid of a lack of public support regarding the private sector's involvement in the definition and development of public policies. Conversely, they may appreciate the support of the industry.
Feasibility in the European context	High	The EU can support governments by promoting regulatory harmonisation regarding PPP, providing advice about how to collaborate with the private sector, assessing the results and sharing good practices. Moreover, fostering innovation and competitiveness of the European industry is a policy clearly aligned with the European Digital Agenda and the EU2020 goals. However, it is unclear whether different governments would support this approach.

7.4.3. Families

The role of families in ensuring that technology is adequately used by students in the education process is particularly relevant. It is not only about having technology at home; rather, it necessitates families having the right ICT skills and being involved in the education process. In fact, this is a two-way process. Students can benefit from their families being more ICT-aware and families can benefit from students using the technology at schools. Schools can act as venues that channel knowledge, experience and expertise to adopt in home computer applications (Peng, 2010). Low-income and minority families could especially benefit from this practice where students act as a gateway for their relatives to become effective Internet users. There is evidence that supports this fact: in the US, the ratio of students' use of advanced Internet services compared to other family members' use is substantially higher in low-income families than in affluent ones (Snyder, 2012, p. 35). Students from low-income families support their less-educated parents to use advanced Internet, thus contributing to bridging their families' digital divide (Zhao, 2009)

However, the truth is that low-income families with less educated parents are not aware of the advantages of the Internet. Children in these families lack technology resources (computers and the Internet). These children are left behind and remain digitally illiterate, creating a vicious circle. The main reason for households not having Internet access is that it is not needed (49 per cent), followed by a lack of skills (37 per cent) and cost barriers (30 per cent) (EC, 2014a, p. 5).

Therefore, policies should be designed to tackle the following main problems: raising awareness about the benefits of the Internet for daily activities, and particularly for students; providing basic ICT skills; and providing financial support. Consequently, three types of policies can be defined in this regard.

7.4.3.1 Carrying out awareness raising campaigns

One way to tackle the problem pertains to altering incentives by increasing the low-income households' demand. This demand can be stimulated by making technology more appealing, thus increasing its perceived utility. This is a top-down approach where governments, supported by other stakeholders such as NGOs and companies, can raise awareness about the use of technology in our daily lives, and particularly in education.

7.4.3.2 Implementing economic incentives

The demand can also be stimulated by providing economic incentives to help low-income families to purchase technology goods and services for the children. However, only providing technology to low-income families may be more harmful than beneficial if it is not accompanied by training policies.

Therefore, financial support for services should also involve training activities for children and their families.

7.4.3.3 Direct provisioning of technology and training services

Governments can directly provide technology services at public facilities — libraries, town halls, schools — to make it easier for low-income families and students to use the Internet out of school and to demonstrate how the Internet can be an effective tool to improve their lives. Governments can cooperate with civil society to support NGOs to provide services which train low-income families.

The result of the assessment for policies to engage low-income families is shown in Table 10.

Table 10: Assessment matrix for the "Families engagement" policies

Criteria	*Adequacy*	*Argument*
Managing uncertainty	Medium	It is unlikely that providing computers to students of low-income families will improve their academic performance. These policies should follow a comprehensive approach aiming to increase household ICT skills and family involvement in the education process
Tackling inequality	High	These policies have a direct effect on inequalities.
Innovative approach	Medium	The expected solutions are not technologically innovative but can promote social innovation.
Stakeholder engagement	High	The role of civil society and NGOs in providing skills and knowledge to low-income families could be very important.
Regulatory feasibility	NA	This approach does not specifically consider regulatory issues.
Budget feasibility	Low	The cost of these policies can be high, particularly if the government provides funding to purchase equipment and connectivity.
Political feasibility	High	The initiative is likely to have high media visibility and political support.
Feasibility in the European context	Medium	The European Union can support governments by providing advice about how to collaborate with NGOs, assessing the results and by sharing good practices. However, it is unclear whether different governments would support the approach.

7.5. Competitiveness policies

7.5.1. Adapting the curriculum

The use of ICT in education is considered a means to improve the outcomes of the educational process, improve the skills of European citizens and their employability and boost competitiveness. However, experts consider that the implementation of these technologies will not bring about these improvements unless the curriculum is simultaneously reformed. This reform can be tackled in a systemic way through a profound revision of the educational scheme and a revision of the core elements of the curriculum. Such a transformation should be driven and coordinated at the European level.

Countries and regions can also opt for a “softer” remodelling of the curriculum by promoting the use of new teaching approaches and new learning methodologies, and the introduction of new skills in the existing subjects. There is a wide range of initiatives and pilot projects in this direction in Europe that can be scaled-up and generalised in the context of the educational system. The UK Government, for example, launched in 2013 the policy “Reforming qualifications and the curriculum to better prepare pupils for life after school” (GOV.UK, 2013b) that resulted in the modifications of the curriculum and the implementation of statutory programmes of study and attainment targets for design and technology in all maintained schools in England from September 2014. The initiative included the provision of resources for the new contents free for schools and teachers (GOV.UK, 2013a).

In any case, reforming the curriculum requires a wide consensus among the education sector, the industry and the society as a whole, and in most cases it would require legislative modifications or adaptations.

The result of the assessment of this policy approach is shown in Table 11.

Table 11: Assessment matrix for the "Adapting the curriculum" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	Low	Although there is growing consensus that the current curriculum is unlikely to fit the requirements of the knowledge society, there is no agreement about how the curriculum should change.
Tackling inequality	Medium	Providing better skills to all students is likely to encourage upward social mobility.
Innovative approach	High	Reforming the curriculum would be a real innovation.
Stakeholder engagement	High	Engaging all stakeholders is a pre-requisite for any reform of the curriculum.
Regulatory feasibility	Medium	A reform of the core elements of the curriculum will require regulatory adaptations.
Budget feasibility	Low	Such a reform would require initial investments.
Political feasibility	Medium	Local interests of regional and national governments could hinder the process.
Feasibility in the European context	High	There are many pilot projects in Europe that could be scaled-up. In addition, Europe has already experienced an important and successful structural reform of higher education (the Bologna Process) and this can be taken as an example for further education reforms.

7.5.2. Designing and officially recognising new assessment methods

Traditional tests might not effectively measure the acquisition of knowledge and, particularly, competences of the 21st century. Evaluating the learning outcomes of new learning methodologies and procedures requires a new assessment approach. This must be a holistic approach that gives room for new assessment strategies, such as formative learning strategies, that helps learners to understand their progress, identify areas for improvement and self-regulate their learning process. These strategies require teachers to adopt the role of mentors or guides, more than traditional evaluators of outcomes.

New assessment policies should comprise the formal recognition of practices, such as self-assessment or peer assessment, and include the use of web-based tools and mobile devices.

Without these new assessment strategies, the benefits if integrating ICT into education cannot be fully exploited.

The result of the assessment of this policy approach is shown in Table 12.

Table 12: Assessment matrix for the "Design and officially recognise new assessment methods" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	Low	There is lack of evidence regarding the benefits of using new assessment methods.
Tackling inequality	Medium	New assessment methods, such as personalised assessment, could address the specific needs of disadvantaged students.
Innovative approach	High	Assessment is an area of education where little innovation has yet been widely applied, so there is great room for progress.
Stakeholder engagement	High	Engaging all stakeholders is a pre-requisite for any reform of the assessment methods.
Regulatory feasibility	Medium	A reform of the core elements of the assessment methods will require regulatory adaptations.
Budget feasibility	High	Such a reform would not require a large investment.
Political feasibility	High	Politicians can support the policy if there is strong support from constituents.
Feasibility in the European context	High	There are many pilot projects in Europe that could be scaled-up. In addition, Europe has already experienced an important and successful structural reform of higher education (the Bologna Process) and this can be taken as an example for further education reforms.

7.5.3. Shaping the role of MOOCs to effectively contribute to lifelong learning

The Survey of Adults Skills shows that adults with higher participation in adult training have also higher literacy, numeracy and information-processing skills (OECD, 2013b). This trend also occurs at the country level: countries more active in adult training activities demonstrate higher levels of skills. Conversely adults with lower skills, who could particularly benefit from training, are less likely to be involved in adult learning activities, thus fostering a vicious circle. This is particularly challenging if considering that unemployment rates in Europe are particularly high for less educated workers (Eurostat, 2014b).

MOOCs are a good illustration of this. Most of the students enrolled in MOOC courses are already well educated (Christensen et al., 2013; Emanuel, 2013) and 70 per cent of students are employed. Less than 10 per cent of students in MOOCs are unemployed (Christensen et al., 2013). MOOCs are not expected to mitigate educational disparities by providing a second chance to less educated population. It raises concerns about whether lifelong learning and technology could increase, rather than decrease, the skills gap without contributing to solving the current problems of high unemployment in Europe. As an example, the Open Education Scoreboard includes 46 MOOCs in Europe (EU, 2014b) to guide students willing to take a course. However most of the MOOCs target higher education students.[24]

Therefore, policies focused on reshaping the role of MOOCs to reach less educated and disadvantaged workers in Europe could contribute to increasing the efficiency of this new way of learning to tackle the problems facing European society. The EU should encourage European universities to develop new courses targeting the specific needs of less educated, unemployed and older populations.

The result of the assessment of this policy approach is shown in Table 13.

Table 13: Assessment matrix for the "Shaping the role of MOOCs to effectively contribute to lifelong learning" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	Low	The role MOOCs play in lifelong learning, particularly regarding employability, remains unclear.
Tackling inequality	Medium	It is expected that MOOCs can provide high quality education to disadvantaged populations. However, early adopters of MOOCs are challenging that expectation.
Innovative approach	High	MOOCs are deeply changing the way higher education is provided to society. It is expected that in the next few years, very different and innovative ways will arise based on the early MOOC experience.
Stakeholder engagement	High	Universities are strongly committed to the open education phenomenon. It is expected that other groups, such as the industry, unions, and civil society will join in the short-term.
Regulatory feasibility	Medium	The main regulatory challenges for MOOCs include accepting new ways of assessing the results (including peer-assessment) and the formal recognition of informal learning.
Budget feasibility	High	One of the main benefits of this approach is its ability to substantially reduce the cost of providing higher education to a large number of students. However, providing a high quality service including personal attention can still be very costly.
Political feasibility	High	Initiatives with high media visibility and low risk levels such as this are likely to gather strong political support.
Feasibility in the European context	High	The EU can support governments and universities by providing a single point of access, aligning different stakeholders, making recommendations about formats and contents, assessing the results, and sharing good practices.

[24] A total of 43 out of 46 (page visited on 12 February 2014).
http://www.openeducationeuropa.eu/en/open_education_scoreboard

7.5.4. Increasing the recognition of informal education

Technology fosters new ways of lifelong training beyond traditional education. New venues for acquiring lifelong knowledge and skills are emerging, such as corporate training, apprenticeship programs and personalised education through open resources. Being able to recognise and assess these new ways of learning is crucial to ensuring European workers are properly integrated into the workforce.

The European Commission can accelerate the creation of alternative credit recognition means shared by the countries to increase the value of quality non-formal education, thus increasing the perceived value of lifelong learning. Moreover, it will ensure that workers improve their skills through these new ways of learning. This can further increase mobility of workers among European countries, although this effect can be diminished by language barriers, particularly for older workers.

The Council of the European Union has issued a recommendation to member states to validate non-formal and informal learning in line with the European Qualifications Framework (EC, 2012a). Usually recognition of non-formal learning is associated with higher education in order to gain access to a higher education program or to gain credits towards an official higher education qualification (Eurydice, 2014).

However, the process in Europe is moving slowly. The US is moving faster; the American Council of Education was established in 1974 to "connect workplace learning with colleges and universities by helping adults gain academic credit for formal courses and examinations taken outside of traditional degree programs" (ACE, 2014). Several programs have been established during this time, such as the Alternative Credit Project and the College Credit Recommendation Service.

The complexity of the European framework with 28 member states and several stakeholders involved in the process within the states, such as trading unions, employers, universities and non-formal education organizations with competing interests, is challenging the process. The European Commission can accelerate the process by drawing upon successful international experiences, aligning the interests of the different stakeholders, sharing best practices, supporting national initiatives to establish national qualification frameworks aligned with the European framework based on learning outcomes, and assessing the results.

The result of the assessment of this policy approach is shown in Table 14.

Table 14: Assessment matrix for the "Increasing the recognition of informal education" policy

Criteria	*Adequacy*	*Argument*
Managing uncertainty	High	This approach will help to address uncertainty about the true value of informal education.
Tackling inequality	High	Although this approach does not reduce inequality, it can facilitate disadvantage populations having access to quality, lifelong training.
Innovative approach	Medium	By increasing the perceived value of non-formal learning, innovative ways of using technology to provide lifelong learning will emerge.
Stakeholder engagement	High	It is expected that the industry, unions, NGOs and civil society will strongly support these policies. Conversely, universities can oppose the recognition of informal education due to vested interests.
Regulatory feasibility	Medium	This is a regulatory policy. The main challenge is accepting new ways of formally recognising informal learning in a homogeneous way throughout Europe.

Budget feasibility	High	One of the benefits of this approach is its ability to substantially increase the way people can learn. The policy is not expected to be very costly.
Political feasibility	High	Initiatives with high media visibility and strong stakeholders support are likely to gather strong political support.
Feasibility in the European context	Medium	The EU can support governments by aligning the interests of different stakeholders, making regulatory recommendations, assessing the results, and sharing good practices.

7.6. Cross-cutting policies

7.6.1. Creating tools to properly evaluate policies

One of the main challenges affecting technology-related educational policies is the lack of reliable information about the effects of the different intervention on educational outcomes. Without that information it is difficult to carry out research to analyse the effectiveness of public policies that can help to decide to maintain, reinforce, or cancel current policies and to design new policies. In fact, when undertaking this analysis, it was difficult to find reliable data about detailed uses of educational technology and its effect on educational performance. A lack of adequate datasets about the use of technology is particularly relevant when considering higher and lifelong education.

Creating an open[25] and homogeneous European longitudinal dataset including extensive information about technology use could substantially improve the quality of educational technology policies in the medium-term. Researchers and analysts could draw upon this dataset to assess the benefits of the different policies. Moreover, this dataset should include information about educational performance and medium-term as well as lifelong outcomes. It is likely that not only short-term educational performance but lifelong achievements are improved by educational technology policies that promote the skills and knowledge required in the network society. The EU can promote the creation of this knowledge at the European level that can further be used to advise national governments about their specific policies. Having the best research knowledge about the effect of technological education on educational and lifelong outcomes can represent a crucial competitive advantage for Europe.

However, creating this knowledge can be costly and challenging in the European environment, which includes 28 countries with specific interests, assessment methods and policies. Short-term electoral interests could also hinder this policy. Although some short-term conclusions may be drawn, it is likely than most of the results will arise in the medium- or long-term. Moreover, quantitative evidence is sometimes dangerous if the analysis and conclusions are flawed (Gorard, 2014) or are opportunistically used (Group, 2014).

The result of the assessment of this policy approach is shown in Table 15.

[25] Excluding sensible data or data that cannot be anonymised.

Table 15: Assessment matrix for "Cross-cutting policies

Creating tools to properly evaluate policies"

Criteria	*Adequacy)*	*Argument*
Managing uncertainty	High	Effectively assessing the policies will substantially reduce uncertainty by better understanding the relationship between causes and effects.
Tackling inequality	High	Although this approach does not reduce inequality, it can contribute to understanding the effect of different interventions on inequality.
Innovative approach	High	These tools will contribute to promoting research about technological education and its effect on pedagogical innovation and short-term and long-term impacts.
Stakeholder engagement	High	Correctly assessing the policies includes analysing the role of the different stakeholders in the process.
Regulatory feasibility	Medium	This approach does not specifically consider regulatory issues, however, it can promote the analysis of regulatory issues during the assessment of results.
Budget feasibility	High	The cost of assessing the policies at a European scale can be high, however, it is much lower than making substantial investments in infrastructure and services without knowing the true outcomes.
Political feasibility	Low	Vested interests of different stakeholders and certain cultural barriers (low transparency) can hinder the evaluation process.
Feasibility in the European context	Medium	This approach might face political and administrative barriers at the national and regional levels.

8. CONCLUSIONS

The EU is facing a challenging situation with stagnated GDP growth, very high unemployment rates, and an aging labour workforce. China and other Asian economies are also performing substantially better in education achievements than the EU and other advanced Western countries. This is particularly relevant for the EU because the relationship between education performance and macro-economic indicators seems to be more intense within the EU than in other parts of the world, particularly for unemployment rates. It is expected that educational technology will contribute to improving education achievements and increasing the competitiveness of EU workers. However, compelling evidence of the benefits of technology on education remains elusive.

In order to understand the role of educational technology so as to define polices to address these challenges, the main technology trends and their effect on the new ways of teaching and learning has been analysed; furthermore, how the different educational stakeholders shape this process has also been examined. Other relevant considerations, such as the economic impact of technology in education, whether educational technology can foster inequalities, regulation issues, and the importance of carefully evaluating educational technology policies have also been assessed.

In analysing these topics, the main conclusion is that educational technology is not a single and simple intervention than can improve education; rather, it comprises a wide array of technologies, tools, services, and methodologies that, if adequately combined, can help students and teachers throughout the educational process to better achieve their goals. Technology alone does not yield better education outcomes; rather educational outcomes are improved by the manner in which technology is effectively integrated into the educational process.

Nevertheless, the relevant question is not if governments should invest in educational technology (not investing in technology is not an option nowadays); rather, the question is how should governments allocate money in order to add more value to the educational system through technology. The only answer is to think carefully about the choices, and make decisions based on evidence about how technology can be integrated into the education system to truly improve the abilities, knowledge, and skills of students so they may perform better in the knowledge society.

Policy-makers can chose from several policy options to confront this challenge. Technology has to be deployed at the school level taking into account the strong uncertainty regarding the benefits of specific technologies in a fast evolving environment. Therefore, options should be based on existing evidence and fostering flexible models that can be easily adapted to evolving needs. Inequality, both at the school and individual level, is another challenge that policies should tackle. The main education stakeholders, namely teachers, families and the industry, should be strongly involved in the process. The successful integration of technology into the education process is not about the technology itself; rather it is about teachers having the skills, abilities and methodological tools to make use of the technology options. Families contribute to children properly using the technology if adequate digital environments are created at the household level. The industry can provide innovative services, contents and tools by working closely with governments. Less educated and older workers are highly unlikely to be involved in lifelong learning, particularly when delivered through innovative ways. Therefore, using technology in education can improve competitiveness of workers but it can yield strong knowledge gaps if the specific needs of less educated and older workers are not taken into account. In this complex environment, we must learn lessons from our experiences. Current uncertainty about the short- and medium-term impact of integrating technology in education should be minimised by fostering research based on evidence to understand the casual relationship between technology and education achievements, depending on contextual factors of the EU.

In summary, what matters most is not the technology itself, but how it is integrated into the complex educational system. Although a clear response does not exist, we expect that this report will support EU policy-makers to better align their policies with the challenges confronting EU society.

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10. ANNEXES

10.1. List of countries used in the international benchmarking

Table 16 shows list of countries used in the international benchmarking using the PISA 2012 dataset ordered by group while Table 17 shows the list of countries using the Survey of Skills (PIAAC) dataset.

Table 18 shows the list of EU countries used in the lifelong learning analysis within the EU using the Survey of Skills (PIAAC) dataset.

Table 16: List of countries used in the international benchmarking based on PISA 2012

GROUP	COUNTRY	ABR
AF	Tunisia	TN
AM	Canada	CA
AM	United States	US
AS	Indonesia	ID
AS	Japan	JP
AS	Kazakhstan	KZ
AS	Korea	KR
AS	Malaysia	MY
AS	Singapore	SG
AS	Thailand	TH
AS	Vietnam	VN
BRIC	Brazil	BR
BRIC	Chinese-Taipei	TA-CH
BRIC	Hong Kong-China	HK
BRIC	Macau-China	MO
BRIC	Russian Federation	RU
BRIC	Shanghai-China	SH-CH
EU	Albania	AL
EU	Iceland	IS
EU	Liechtenstein	LI
EU	Montenegro	ME
EU	Norway	NO
EU	Serbia	RS
EU	Switzerland	CH
EU	Turkey	TR
EU28	Austria	AT
EU28	Belgium	BE
EU28	Bulgaria	BG
EU28	Croatia	HR
EU28	Cyprus	CY

EU28	Czech Republic	CZ
EU28	Denmark	DK
EU28	Estonia	EE
EU28	Finland	FI
EU28	France	FR
EU28	Germany	DE
EU28	Greece	GR
EU28	Hungary	HU
EU28	Ireland	IE
EU28	Italy	IT
EU28	Latvia	LV
EU28	Lithuania	LT
EU28	Luxembourg	LU
EU28	Netherlands	NL
EU28	Poland	PL
EU28	Portugal	PT
EU28	Romania	RO
EU28	Slovak Republic	SK
EU28	Slovenia	SI
EU28	Spain	ES
EU28	Sweden	SE
EU28	United Kingdom	GB
LA	Argentina	AR
LA	Chile	CL
LA	Colombia	CO
LA	Costa Rica	CR
LA	Mexico	MX
LA	Peru	PE
LA	Uruguay	UY
ME	Dubai (UAE)	DU
ME	Israel	IL
ME	Jordan	JO
ME	Qatar	QA
ME	United Arab Emirates	AE
OC	Australia	AU
OC	New Zealand	NZ

Table 17: List of countries used in the international benchmarking based on the Survey of Adult Skills (PIAAC)

GROUP	COUNTRY	ABR
AM	Canada	CA
AM	United States	US
AS	Japan	JP
AS	Korea	KR
EU	Norway	NO
EU28[26]	Austria	AT
EU28	Czech Republic	CZ
EU28	Denmark	DK
EU28	Estonia	EE
EU28	Finland	FI
EU28	France	FR
EU28	Germany	DE
EU28	Ireland	IE
EU28	Italy	IT
EU28	Netherlands	NL
EU28	Poland	PL
EU28	Slovak Republic	SK
EU28	Spain	ES
EU28	Sweden	SE
OC	Australia	AU

[26] The figures refer to these 14 EU28 countries as EU14.

Table 18: List of EU countries used in the lifelong learning analysis based on the Survey of Adult Skills (PIAAC)

GROUP	COUNTRY	ABR
EU28	Czech Republic	CZ
EU28	Denmark	DK
EU28	Estonia	EE
EU28	Finland	FI
EU28	France	FR
EU28	Germany	DE
EU28	Ireland	IE
EU28	Italy	IT
EU28	Netherlands	NL
EU28	Poland	PL
EU28	Slovak Republic	SK
EU28	Spain	ES
EU28	Sweden	SE
EU28	United Kingdom	UK

10.2. List of figures and descriptive statistics

Table 19 shows the list of figures and the descriptive statistics of the dataset used in each figure. The regressions represented in the charts are made using the whole sample (gray dotted line) and the sample without outliers (blacked dotted line). The outliers are chosen based on the 1.5 Inter Quartile Range (IQR) rule.

Table 19: Figures and statistics

Figure	Chart	N	Pearson-R	Variable	Sample mean[27]	sd	Min	Q2	Median	Q3	Max	Outliers (1.5 IQR rule)
Figure 19: EU27 macro-indicators value and trend compared to other countries	top-left	34	0,19	Unemployment rate 2012	6,08	2,7	2	4,15	5,75	7,2	12,8	Albania, Montenegro, Serbia
				Percentage change unemp, rate 09-12	-11,89	13,15	-36,54	-16,72	-12,97	-4,69	17,13	Macau-China, Qatar, Thailand
	top-right	34	0,33	Unemployment rate of youth (15-24) 2012	13,76	6,1	4,2	9,32	12,85	16,85	29,3	Jordan, Montenegro, Serbia
				Percentage change unemp, rate of youth 09-12	-9,98	12,93	-38,24	-15,52	-9,91	-1,01	20,34	Macau-China, Qatar, Thailand
	botton-left	39	-0,15	Competitive Global Index 2012	4,7	0,54	3,87	4,25	4,65	5,1	5,72	
				Percentage change CGI 09-12	2,04	2,45	-2,19	0,08	2,19	3,43	7,38	Qatar
	botton-right	39	0,05	GDP per capita 2012 (2014 US$ x 1,000)	25,82	24,82	1,75	6,42	14,09	41,69	92,63	Norway
				Percentage change GDP per capita 09-12	35,91	22,8	-3,71	19,58	37,72	53,35	88,93	
Figure 20: EU27 countries' macro-economic indicators value and trend	top-left	24	0,41	Unemployment rate 2012	9,73	3,53	4,3	7,38	9,35	12,53	15,8	Greece, Spain
				Percentage change unemp, rate 09-12	15,45	30,47	-29,87	-4,84	6,63	28,04	80,88	Cyprus, Greece
	top-right	24	0,44	Unemployment rate of youth (15-24) 2012	22,96	7,9	8,1	19,17	23,25	28,13	37,7	Croatia, Greece, Spain
				Percentage change unemp, rate of youth 09-12	18,2	34,65	-26,36	-9,75	10,57	31,8	104,6	
	bottom-left	27	0,29	Competitive Global Index 2012	4,72	0,53	3,86	4,33	4,51	5,21	5,55	
				Percentage change CGI 09-12	0,8	3,27	-5,32	-0,68	1,72	2,64	7,12	
	bottom-right	25	-0,24	GDP per capita 2012 (2014 US$ x 1,000)	27,71	14,74	7,02	14,17	22,4	42,6	56,36	Luxembourg
				Percentage change GDP per capita 09-12	0,5	9,8	-21,96	-6,3	-0,59	5,78	20,99	Sweden
Figure 21: PISA math scores 2012 and trend in EU27 compared to		39	-0,03	PISA math score 2012	462,25	67,6	368	407,5	456,5	514,5	613	
				Percentage change PISA math score 09-12	0,79	2,2	-4,21	-0,54	1,08	2,17	4,58	Kazakhstan

[27] The figures show the sample means rather than the worldwide averages

Figure	Chart	N	Pearson-R	Variable	Sample mean[27]	sd	Min	Q2	Median	Q3	Max	Outliers (1.5 IQR rule)
other countries												
Figure 22: PISA math scores below level 2 in 2012 and trend in EU27 compared to other countries		39	-0,12	Pisa math score below level 2 2012	38,57	23,56	3,8	15,5	36,2	59,08	75,7	
				Difference 09-12 PISA math score below level 2	-0,1	3,86	-7,5	-1,95	-0,25	3,12	8,2	Kazakhstan
Figure 23: PISA scores 2012 and trend in EU27 countries		25	0,17	PISA math score 2012	492,04	19,76	445	481,2	492,5	502,2	523	Bulgaria
				Percentage change PISA math score 09-12	0,33	2,08	-3,24	-0,49	0,2	1,49	4,65	Finland
Figure 24: PISA math scores below level 2 in 2012 and trend in EU27 countries		25	0,47	Pisa math score below level 2 2012	21,59	5,95	10,5	17,5	21,4	25,17	35,7	Bulgaria, Romania
				Difference 09-12 PISA math score below level 2	0,49	3,3	-6,1	-1,1	-0,1	1,5	6,5	
Figure 25: Relationship between PISA math score in 2012 and macro-indicators in EU27 compared to other countries	top-left	37	-0,33	PISA math score 2012	465,12	68,07	368	408,5	465	521,2	613	
				Unemployment rate 2012	5,66	2,95	0,6	3,55	5,3	7,05	12,8	Albania, Montenegro, Serbia
	top-right	37	-0,31	PISA math score 2012	465,34	67,81	368	408,5	465	521,2	613	
				Unemployment rate of youth (15-24) 2012	12,81	6,61	1,7	8,75	11,7	16,65	29,3	Jordan, Montenegro, Serbia
	bottom-left	40	0,66	PISA math score 2012	461,47	66,88	368	408	449	511	613	
				Competitive Global Index 2012	4,72	0,54	3,87	4,26	4,69	5,12	5,72	
	bottom-right	39	0,41	PISA math score 2012	460,75	67,63	368	407,5	448,5	514,5	613	
				GDP per capita 2012 (2014 US$ x 1,000)	25,82	24,82	1,75	6,42	14,09	41,69	92,63	Norway
Figure 26: Relationship between percentage of students below level 2 in PISA math scores and unemployment in EU27 compared to other countries	left	37	0,33	Pisa math score below level 2 2012	37,63	23,74	3,8	14,02	33,4	56,82	75,7	
				Unemployment rate 2012	5,66	2,95	0,6	3,55	5,3	7,05	12,8	Albania, Montenegro, Serbia
	right	37	0,31	Pisa math score below level 2 2012	37,41	23,48	3,8	14,02	33,4	56,82	75,7	
				Unemployment rate of youth (15-24) 2012	12,81	6,61	1,7	8,75	11,7	16,65	29,3	Jordan, Montenegro, Serbia
Figure 27: Relationship between PISA math score in 2012 and macro-indicators in EU27 countries	top-left	24	-0,34	PISA math score 2012	495,26	18,92	445	483,5	495	510	523	Bulgaria
				Unemployment rate 2012	9,71	3,52	4,3	7,38	9,35	12,15	15,8	Greece, Spain
	top-right	23	-0,48	PISA math score 2012	496,36	18,6	445	485,5	497	512	523	Bulgaria
				Unemployment rate of youth (15-24) 2012	22,73	7,99	8,1	18,95	22,8	27,45	37,7	Croatia, Greece, Spain
	bottom-left	26	0,63	PISA math score 2012	493,12	20,08	445	482	494	506	523	Bulgaria
				Competitive Global Index 2012	4,74	0,53	3,86	4,34	4,55	5,22	5,55	
	bottom-	25	0,43	PISA math score 2012	493,25	20,5	445	481,2	494,5	508	523	Bulgaria

Figure	Chart	N	Pearson-R	Variable	Sample mean[27]	sd	Min	Q2	Median	Q3	Max	Outliers (1.5 IQR rule)
	right			GDP per capita 2012 (2014 US$ x 1,000)	29,63	15,06	8,44	16,89	26,35	43,4	56,36	Luxembourg
Figure 28: Relationship between percentage of students below level 2 in PISA math scores and unemployment in EU27 countries	left	23	0,4	Pisa math score below level 2 2012	20,85	5,35	10,5	17,1	20,55	24,85	29,9	Bulgaria, Romania
				Unemployment rate 2012	9,83	3,55	4,3	7,5	9,9	12,5	15,8	Greece, Spain
	right	22	0,51	Pisa math score below level 2 2012	20,42	5,07	10,5	16,9	20,1	24,7	28,1	Bulgaria, Romania
				Unemployment rate of youth (15-24) 2012	22,73	8,18	8,1	18,72	22,5	27,78	37,7	Croatia, Greece, Spain
Figure 29: Relationship between education and skills by age in EU14 compared to other countries	left	7	0,81	Skills score numeracy 16-24 yr,	273,41	6,88	267	268,8	270,5	278,4	283,2	United States
				PISA math score 2012	512,02	25,78	482	495,1	504	527	554	
	right	6	-0,05	Skills score numeracy	267,57	6,16	260,7	263,9	266,6	269,3	278,3	Japan
				Skills score numeracy 16-24 yr,	271,45	5,51	267	268,3	270,1	270,9	280,9	United States
Figure 30: Relationship between education and skills by age in EU14 countries	left	15	0,48	Skills score numeracy 16-24 yr,	271,9	10,94	251,3	264,7	276,5	278,5	285,4	
				PISA math score 2012	501,79	15,59	478	487,5	500,5	517	523	
	right	15	0,96	Skills score numeracy	266,69	13,53	245,8	254,9	273,1	277	282,2	
				Skills score numeracy 16-24 yr,	271,9	10,94	251,3	264,7	276,5	278,5	285,4	
Figure 31: Relationship between percentages of adults scoring at level 1 or below in problem solving in technology rich environments by age in 2012 in EU14 compared to other countries		7	0,8	Youth 16 to 24 scoring below level 2 in problem solving	39,91	6,04	30,5	38,9	39,82	40,94	49,4	
				Adults scoring below level 2 in problem solving	42,28	3,68	38,1	39,95	41,08	44	48,9	Japan
Figure 32: Relationship between percentages of adults scoring at level 1 or below in problem solving in technology rich environments by age in 2012 in EU14 countries		14	-0,19	Youth 16 to 24 scoring below level 2 in problem solving	40,37	4,93	33,3	36,7	41,45	43,03	47,7	
				Adults scoring below level 2 in problem solving	42,57	2,72	37,7	41,02	42,45	44,65	46,8	Poland
Figure 33: Relationship between macro-indicators and technology penetration at schools in EU27 compared to other countries	top-left	38	0,67	GDP per capita 2012 (2014 US$ x 1,000)	24,66	24,14	1,75	6,34	13,11	39,43	92,63	Norway
				Computers per student	0,51	0,24	0,14	0,35	0,49	0,66	1,1	Australia
	top-right	39	0,02	GDP per capita 2012 (2014 US$ x 1,000)	25,82	24,82	1,75	6,42	14,09	41,69	92,63	Norway
				Expected work requiring Internet access	0,34	0,08	0,17	0,29	0,35	0,4	0,48	Norway
	bottom-	39	0,59	Internet penetration	66,19	19,7	21,7	52,08	66,75	84,92	96,5	

Figure	Chart	N	Pearson-R	Variable	Sample mean[27]	sd	Min	Q2	Median	Q3	Max	Outliers (1.5 IQR rule)
	left			Computers per student	0,52	0,24	0,14	0,35	0,5	0,67	1,1	Australia
	bottom-right	39	-0,15	Internet penetration	65,97	19,4	21,7	52,08	66,75	84,92	96,5	
				Expected work requiring Internet access	0,34	0,08	0,17	0,29	0,35	0,4	0,48	Norway
Figure 34: Relationship between macro-indicators and technology penetration at schools in EU27 countries	top-left	25	0,15	GDP per capita 2012 (2014 US$ x 1,000)	28,04	15,27	7,02	14,17	22,4	42,6	56,36	Luxembourg
				Computers per student	0,64	0,19	0,24	0,54	0,64	0,74	1,02	Austria
	top-right	26	-0,07	GDP per capita 2012 (2014 US$ x 1,000)	28,76	15,4	7,02	14,85	24,37	43,2	56,36	Luxembourg
				Expected work requiring Internet access	0,35	0,07	0,24	0,29	0,34	0,4	0,48	
	bottom-left	26	0,45	Internet penetration	75,78	13,13	49,8	66,25	75	85,48	94,8	
				Computers per student	0,65	0,2	0,24	0,55	0,64	0,76	1,02	Austria
	bottom-right	27	-0,33	Internet penetration	75,96	12,9	49,8	67	75,2	84,75	94,8	
				Expected work requiring Internet access	0,34	0,07	0,22	0,28	0,34	0,39	0,48	
Figure 35: Relationship between technology penetration at schools and PISA math scores in EU27 compared to other countries		39	0,45	Computers per student	0,52	0,24	0,14	0,35	0,5	0,67	1,1	Australia
				PISA math score 2012	460,35	67,41	368	407,5	448,5	513,5	613	
Figure 36: Relationship between expected computer use in education and PISA math scores in EU27 compared to other countries	top-left	39	-0,42	Expected lessons requiring Internet access	0,27	0,07	0,15	0,21	0,26	0,32	0,42	Norway
				PISA math score 2012	460,75	67,63	368	407,5	448,5	514,5	613	
	top-right	37	-0,14	Expected assignments requiring Internet access	0,45	0,08	0,26	0,41	0,45	0,51	0,59	Iceland, Norway, Vietnam
				PISA math score 2012	459,87	68,34	368	407	448	518	613	
	bottom-left	39	-0,49	Expected homework requiring Internet access	0,33	0,09	0,1	0,26	0,32	0,4	0,51	Norway
				PISA math score 2012	460,75	67,63	368	407,5	448,5	514,5	613	
	bottom-right	39	-0,42	Expected work requiring Internet access	0,34	0,08	0,17	0,29	0,35	0,4	0,48	Norway
				PISA math score 2012	460,75	67,63	368	407,5	448,5	514,5	613	
Figure 37: Relationship between technology penetration at schools and PISA math scores in EU27 countries		25	0,22	Computers per student	0,66	0,2	0,24	0,54	0,65	0,77	1,02	Austria
				PISA math score 2012	492,58	20,33	445	481,2	492,5	504,2	523	Bulgaria
Figure 38: Relationship between expected computer use in	top-left	25	-0,33	Expected lessons requiring Internet access	0,25	0,07	0,14	0,2	0,23	0,3	0,44	Romania
				PISA math score 2012	495,12	17,77	453	483,5	494,5	508	523	Bulgaria

Figure	Chart	N	Pearson-R	Variable	Sample mean[27]	sd	Min	Q2	Median	Q3	Max	Outliers (1.5 IQR rule)
education and PISA math scores in EU27 countries	top-right	25	-0,11	Expected assignments requiring Internet access	0,45	0,09	0,28	0,39	0,46	0,5	0,67	Greece
				PISA math score 2012	494,79	18,65	445	483,5	494,5	508	523	Bulgaria
	bottom-left	26	-0,42	Expected homework requiring Internet access	0,3	0,06	0,19	0,25	0,29	0,36	0,41	
				PISA math score 2012	493,12	20,08	445	482	494	506	523	Bulgaria
	bottom-right	26	-0,47	Expected work requiring Internet access	0,34	0,07	0,22	0,28	0,34	0,38	0,48	
				PISA math score 2012	493,12	20,08	445	482	494	506	523	Bulgaria
Figure 39: Relationship between technology use and percentage of students performing below level 2 in PISA math scores in EU27 compared to other countries	left	39	-0,51	Computers per student	0,52	0,24	0,14	0,35	0,5	0,67	1,1	Australia
				Pisa math score below level 2 2012	39,24	23,37	3,8	15,95	40,45	59,08	75,7	
	right	39	0,4	Expected work requiring Internet access	0,34	0,08	0,17	0,29	0,35	0,4	0,48	Norway
				Pisa math score below level 2 2012	39,17	23,42	3,8	15,5	40,45	59,08	75,7	
Figure 40: Relationship between technology use and percentage of students performing below level 2 in PISA math scores in EU27 countries	left	24	-0,22	Computers per student	0,66	0,2	0,24	0,57	0,66	0,78	1,02	Austria
				Pisa math score below level 2 2012	21,71	6,06	10,5	17,3	21,8	25,45	35,7	Bulgaria, Romania
	right	25	0,27	Expected work requiring Internet access	0,33	0,07	0,22	0,28	0,33	0,38	0,47	
				Pisa math score below level 2 2012	21,59	5,95	10,5	17,5	21,4	25,17	35,7	Bulgaria, Romania
Figure 41: Relationship between numeracy skills and unemployment rates in EU14 and compared to other countries	left	7	-0,65	Skills score numeracy	265,46	7,92	252,8	262	265,5	268,8	278,3	Japan
				Unemployment rate 2012	6,13	2,66	3,2	4,2	5,5	7,65	10,49	
	right	14	-0,57	Skills score numeracy	268,18	12,7	246,6	256,6	274	277,7	282,2	
				Unemployment rate 2012	9,02	3,14	4,3	7,12	8,95	10,55	14,7	Spain
Figure 45: Relationship between population ages (0-14 and 65 and above) in EU27 compared to other countries and within EU27 countries	left	39	-0,42	Population 0-14 in 2012 (% of total)	20,45	5,59	11	16	20	24	34	
				Population 65 and above in 2012 (% of total)	9,2	4,15	0,36	6	9	13	17	Japan
	right	26	-0,34	Population 0-14 in 2012 (% of total)	15,15	1,43	13	14	15	16,76	18	
				Population 65 and above in 2012 (% of total)	16,77	2,2	12	16	17	18	21,1	Ireland

Educational technology encompasses a wide array of technologies and methodologies that are shaped by stakeholders' behaviours and affected by contextual factors that, if adequately mixed, can contribute to students and teachers better achieving their goals.

Such a wide and complex task cannot be addressed by a simple and single intervention. Comprehensive on-going policies are required, covering technology, methodology, economic and regulatory aspects; in addition, such policies are dependent on strong stakeholder engagement. This is a new process where we must learn by doing; therefore, carefully assessing the results of the different interventions is crucial to ensuring success.

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