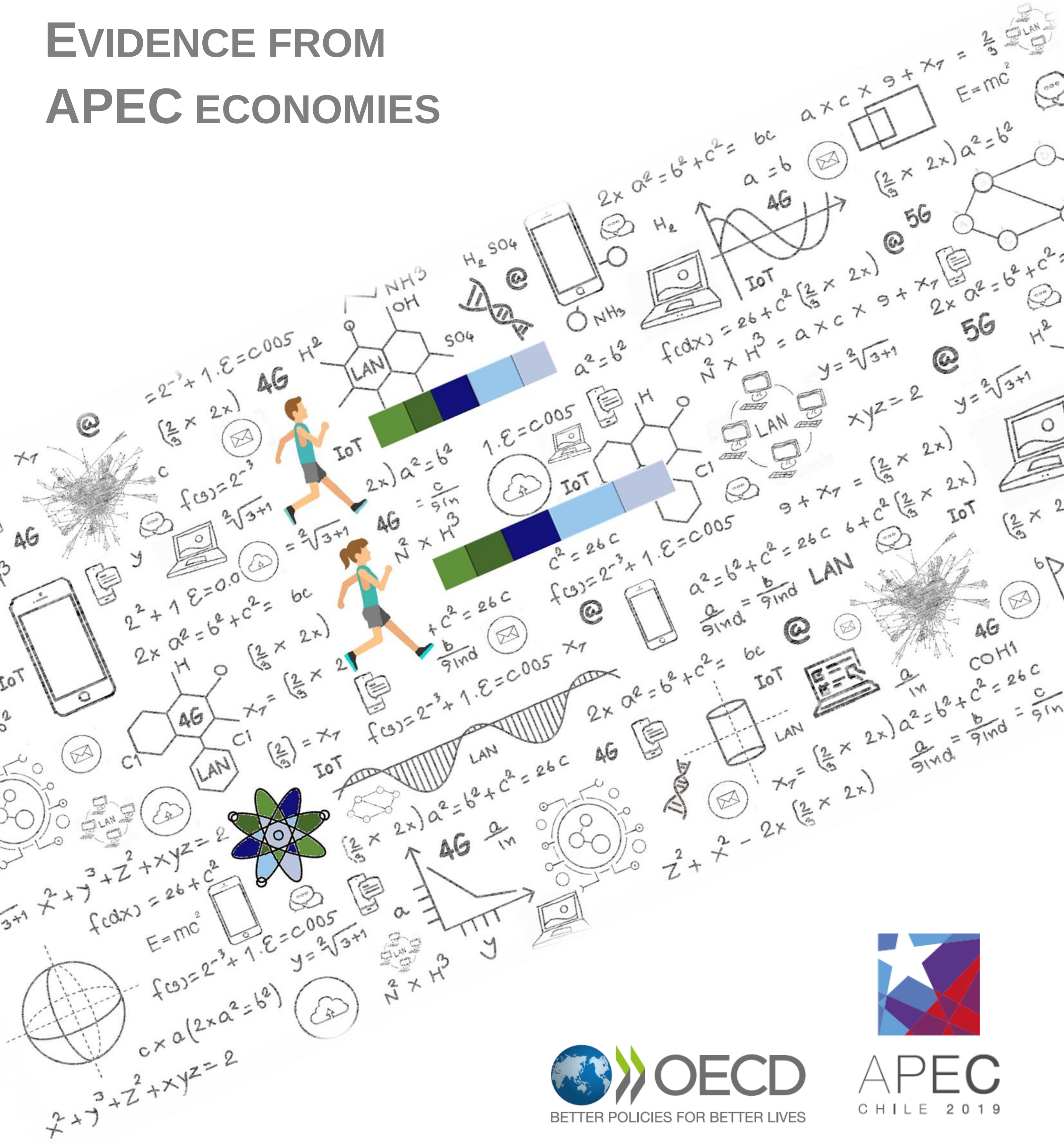
THE ROLE OF EDUCATION AND SKILLS IN BRIDGING THE DIGITAL GENDER DIVIDE

EVIDENCE FROM APEC ECONOMIES



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This report of the Organisation for Economic Co-operation and Development has been prepared at the request of the Chilean Government, in the context of the Asia-Pacific Economic Cooperation (APEC) Chile's 2019 Women, SMEs and Inclusive Growth Priority. It aims to strengthen the evidence base in support of APEC discussions on understanding and bridging the digital gender gap in APEC economies.

The cover embeds part of Figure 24, illustrating the task-based skill distances that men and women need to bridge in order to move to a different occupation.

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Foreword

For both women and men, being able to harness the potential of the digital transformation is a keystone of more sustainable and inclusive economies and societies. However, women are still lagging behind in their ability to access, use, and afford digital tools. They are also facing cultural barriers and stereotypes that affect their expectations and may lead them to choose career paths that are not necessarily those that the increasingly digitalised and interconnected world rewards. Early and systemic policy interventions, particularly in the education systems, but also those aimed at changing cultural norms and tackling stereotypes, are crucial to address these gaps and avoid them being further accentuated as the digital transformation unfolds.

Recognising that gender equality is essential to ensure that men and women can develop their full potential in the digital world, Chile has taken the lead in the framework of APEC and defined "Women, SMEs and Inclusive Growth" and "Digital Society" as two of its key priorities for its 2019 APEC host year. It is in this context that Chile has invited the OECD to analyse "The Role of Education and Skills in Bridging the Digital Gender Divide: Evidence from APEC Economies". The report contributes to APEC's previous efforts to introduce a cross-cutting gender angle in its agenda, signalling the strategic importance of this issue for APEC's post-2020 vision. Building on its leadership on gender issues, the OECD is proud to have contributed to these goals, as part of its growing engagement with APEC economies and in support of Chile's priorities.

There is no doubt that the digital gender divide should be addressed in all APEC economies. In 2017, women in nearly all APEC economies used the Internet to a lesser extent than men. Gender differences also emerge with respect to the skills and confidence in using digital technologies. For example, fewer women apply for jobs online and use Internet-banking services than men. The gender gap tends to be larger when female educational attainment and income are relatively low, and they are especially so relative to the costs of mobile handsets, digital devices or data.

Beyond identifying gender differences in access, use, and affordability, the report also highlights many other obstacles rooted in socio-cultural norms that are still preventing women from playing an active role in the digital revolution. Inherent biases and limitations in our societies that are reflected in education systems curtail women and girls' ability to benefit from the opportunities offered by the digital transformation and create barriers that are magnified later in life. For instance, girls and women are much more likely to experience computer anxiety than boys and men. On average, at the age of 15, boys are more than twice as likely as girls to expect to work as scientists or engineers. When it comes to doctoral holders in STEM fields across APEC economies, on average only 35% are women.

At the same time, women are equally represented or even over-represented in other – "less-technical" – fields, such as health and welfare and education, i.e. "caring" types of educational paths.

The report also makes an important contribution to APEC discussions on the digital gender divide by providing new evidence on the implications of the digital transformation on skills, noting that this impact is gender-differentiated and can reinforce existing gaps, including gender pay gaps, and limiting women engagement in e-commerce. It also sheds lights on the importance of skills such as self-organisation, management and communication and advanced numeracy, which are in high demand in digitally intensive sectors and are currently more often displayed by men than women.

Policy action is key to support APEC economies in bridging digital gender divides. Formative years are particularly important, and education plays a crucial role in shaping the opportunities for digital skills development. Early interventions aimed at tackling gender gaps in attitudes and competences that are key to succeed in ICT-rich environments are also the most cost-effective and with the longest-lasting impact. Against this backdrop, the report identifies four key education-related areas for action that, taken together, can facilitate systemic change and break down the barriers to women's digital empowerment: promoting ICT use, skills and learning; empowering educators and making them active agents of change; changing attitudes and expectations; and preventing discrimination and gender-based violence – which begins by addressing teachers' biases and gender stereotypes in textbooks.

The road ahead is uphill. Many APEC economies are already taking effective steps to move towards greater gender inclusion, but much remains to be done. Given the severe economic and social penalties imposed by the digital gender divide, inaction is not an acceptable option. An inclusive digital future is within reach - but we must act now.

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Executive summary

Without the right policies, obstacles that women have encountered - and continue to face - in the analogue world are likely to grow exponentially in the digital future. The barriers to gender equality are numerous and diverse. Some are deeply rooted in the past, while others are unique to the digital world. Hurdles to access and affordability, inherent biases and socio-cultural norms, coupled with lack of educational opportunities and skills, among others, curtail women's ability to fully benefit from the digital transformation.

However, these barriers are in no way insurmountable. In addition to identifying some of the main obstacles that women face in the digital world, this report shows how policy interventions can help pave the way to greater gender inclusion, with a focus on the fundamental role of education and training in bridging the (digital) gender divide.

The report finds that ***in many APEC economies, women use technology less often than men.*** In 2017, women in nearly all APEC economies, except the United States, used the Internet to a lesser extent than men. Peru and Indonesia exhibited the widest digital gender divide among the APEC economies for which data are available. This phenomenon is not limited to APEC economies: worldwide there are around 250 million fewer women online compared to men worldwide.

Affordability may prevent women from accessing and benefiting from digital technologies. In some APEC economies, particularly in rural areas and among the socio-economically disadvantaged, affordability can be a major barrier to the digital world. Affordability not only refers to the financial resources needed to purchase and operate digital technologies but also to human resources. This includes the time needed to learn how to use digital tools. However, time poverty disproportionally affects women. Among other factors, this often results from the unpaid work that women take on within the home and the care they provide for children and the elderly.

Lack of skills and confidence may also keep women at the margins of the digital revolution. In some APEC economies, even when women know about digital technologies and have access to them, they may lack the skills and confidence to actually use them. Such "technophobia" is often a result of concurrent factors including education, employment status and income level. For example, in Mexico and China, 31% of women (versus 15% of men) who use mobile phones are not using mobile Internet because they report not knowing how to access it.

Importantly, ***the negative experiences that many girls and women endure online can have negative consequences on their lives.*** Cyber-bullying, gender stereotyping and online harassment contribute to frequent reports that women do not feel safe or comfortable taking the centre stage online. This has also led many families to discourage girls from doing so. Such negative experiences online, in media and in social networks, can have a negative impact on the well-being of many young girls and women, with negative spill over effects on their self-confidence, trust and ultimately their mental health and physical safety.

Many barriers preventing women from being active protagonists of the digital revolution are rooted in the opportunities, attitudes and expectations that they are confronted with. In that regard, schools are particularly important as they create a space for education to help tackle the gender digital divide by dismantling gender stereotypes that prevent girls from developing the skills, ambition, and confidence needed to thrive in the digital world. Granting access to (good) education to all individuals, including girls and women who live in disadvantaged conditions or areas, is a necessary condition to bridging the gender the divide both in the analogue world and even more so in the digital world . It is also important to address the lack of role models for many girls, the gender stereotypes informing textbooks, and the personal biases of educational professionals. Too often communities, teachers but also family members exert peer pressure for girls to make choices that conform to stereotypical notions of femininity. As such, girls often receive stereotypical advice when selecting courses, educational pathways and careers. These factors ultimately contribute to economies whereby too few women have the skills, confidence and determination needed to thrive in the digital world, but also whereby too few women are willing to play a leading role in this world even when they have the competences to do so.

The limitations of current education systems create barriers that are magnified later in life. In the face of stereotypes and expectations, girls with high potential may also lack the support they need to thrive when they study ICT at university. Figures related to the share of women tertiary graduates in those APEC economies for which data are available, show that only one out of ten women or less holds a tertiary degree in STEM, although important differences emerge across economies. For example, in 2016, the share of female tertiary graduates in STEM as a percentage of all tertiary graduates ranged between 8% in Mexico and the Republic of Korea, to as low as 4% in Chile and 3% in Japan. When it comes to doctoral studies in STEM fields, only about one third (35%) of degree holders are women, on average across APEC economies and men are almost 3.5 times more likely to have a doctoral degree in ICT.

Education and training should help all individuals, i.e. both men and women, acquire the skills bundles that appear to matter the most in the work of the future. First time analysis of online job openings in Australia; Canada; New Zealand; Singapore; and the United States reveals that the future of work is in the skills mix. On the one hand, ICT-related jobs are increasingly requiring workers not only to be endowed with a solid set of ICT-related skills, such as computer programming, but also with strong soft skills including communication skills, planning skills and teamwork/collaboration skills. On the other hand, all other occupations (i.e. non-ICT occupations) increasingly require all individuals to be endowed with ICT-related skills. Among the skills for which demand has been growing the most in non-ICT occupations there are skills related to "Data Science", "Internet of Things", "Artificial Intelligence" and "Fintech".

In the Fourth Industrial Revolution, the greatest benefits are likely to accrue to those having the ability to perform tasks and cognitive functions that complement what machines can do. These capacities, which include designing digital solutions and adapting or creating machine algorithms, build on advanced reasoning and problem-solving skills and require good mastery of symbolic and formal language. They often build on related skills acquired in mathematics courses, where girls generally – although by no means universally - underperform compared to boys. Reading in the digital medium builds on reading skills acquired in a non-digital environment, but also relies on good navigation skills. Navigation, in turn, requires an awareness of what is known and what is not, and the ability to act upon this knowledge; the ability to organise complex hypertext structures into a coherent mental map; experience in evaluating the relevance of pages; and a repertoire of effective strategies for reading on line. Without these, students find themselves digitally adrift and girls and women tend to underperform in these areas.

Lifelong learning opportunities help keep women in the labour market and facilitate occupational transitions, also those triggered by automation. A first-time analysis on occupational transition indicates that female workers would generally need to bridge greater skills gaps than men in order to move to different occupations. This is true for all workers as well as for women in occupations are at risk of being made redundant due to automation. Mobility away from occupations at high risk of automation (and, more generally mobility away from any occupation) mostly requires acquiring self-organisation and management and communication skills, no matter the gender of the worker.

In those APEC economies that participated in the OECD Survey of Adult Skills (PIAAC) ***important gender wage gaps emerge, which are only partly explained by differences in the skills of men and women.*** The gender wage gap characterises all parts of the economy, with differences emerging between digital-intensive and less digital-intensive industries. Age further penalises women but not men. In APEC economies, having kids and working in a digital intensive industry may lead women to earn 11% less, on average, than their male counterparts.

In addition, age leads to lower returns to skills in all industries in the APEC economies considered. The gender wage gap is more pronounced in digital intensive industries in Singapore; the Russian Federation; the United States; Canada; and Japan while the gender wage gap is relatively more pronounced in less digital intensive industries in economies such as New Zealand; Chile; and the Republic of Korea.

Policy needs addressing the gender wage gap and ensuring that female workers are paid the same if having the same skills and are not discriminated on the basis of age or motherhood. Education, including vocational programmes, may help upskilling or reskilling women after spells outside of paid work related to taking care of family or children.

Caring responsibilities prevent women from upskilling and retraining in rapidly evolving digital sectors. There is a sort of vicious cycle whereby women lag behind in acquiring the right skills at school that is not rectified, but rather magnified, as they strive to progress in their professional careers. While the literacy advantage that women have at age fifteen is narrowed by men before the age of 30, the numeracy advantage of men over women increases with age.

Policy is key to helping economies bridge the digital gender divide. There are many actions that could be implemented to narrow and ultimately erase such gap in schools, universities and workplaces and that could bring about tangible benefits at sustainable costs. Such actions, however, need to be part of a systemic approach and require a high level of commitment from policy makers and other stakeholders to bear fruit. Four key areas for policy action emerge from the analysis presented in this report, with specific interventions and programmes to be prioritised and developed according to local circumstances. Importantly, this entails making considerations about the estimated cost of different programmes (as well as the distribution of costs between governmental and non-governmental stakeholders) and the timeframe needed to bring about the sought benefits.

The four key areas identified as part of a systemic approach are: promoting ICT use, skills and learning; empowering educators and making them active agents of change; changing attitudes and expectations; preventing discrimination and gender-based violence. Taken together, these four areas represent a comprehensive set of actions that can facilitate systemic change among a wide range of stakeholders and can help break down the barriers that prevent female digital empowerment.

Policy changes should involve a wide range of stakeholders, including teachers, school leaders, companies, orientation specialists, university administrators, online operators, digital providers, industry leaders, trainers, NGOs and the legal and judiciary systems. Some policy actions are "must do's" for economies that intend to reduce the digital gender divide. For example, "must do" actions include: raising awareness among teachers about their personal gender biases, making educational materials gender neutral and ending online violence. Other actions are "strategic and structural", and entail important budgetary commitments for non-negligible periods that are likely to bear (very important) results in the long term. These include designing and shaping lifelong learning opportunities to facilitate occupational transitions and promote female engagement in digital sectors, while addressing time poverty among women by providing adequate childcare and family support.

Given the severe economic and social penalties associated with the digital gender divide, the cost of action, which might appear high, is likely to be several times lower than the foreseen cost associated with inaction. The latter may worsen conditions for women in the digital economies of the 21st century and hinder economic development and growth, contribute to widen inequalities and jeopardise the wellbeing of society at large.

There are many examples of APEC economies that are moving in the right direction towards greater gender inclusion. For example, among many others, the NiñaSTEMpueden initiative in Mexico highlights how education systems can become key actors for change and influence stereotypes through role modelling and career orientation for school-aged girls. The NiñaSTEMpueden initiative illustrates that when the will to fight for equality between men and women as well as girls and boys is present, much is possible at little financial cost.

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INTRODUCTION

Equal access to technology and learning opportunities, as well as policy interventions, are instrumental to increase women's economic empowerment. Nevertheless, the proportion of women using the Internet is 12% lower than the proportion of men using the Internet worldwide; barriers to access, lack of education, skills and technological literacy and inherent gender biases and socio-cultural norms, are at the root of gender-based digital exclusion (OCDE, 2018b).

It is estimated that doubling the number of women and girls online would generate about USD 13 to 18 billion in GDP across developing economies (Intel and Dalberg, 2012). Nevertheless, solely providing access is not sufficient. A wider focus involving key stakeholders, including infrastructure capacity, essential skills training and digital inclusion, as well as society at large, is necessary.

This calls for a multidimensional approach aiming to avoid gender stereotyping from the very early age, leveraging on key stakeholders, including the family and the education system, and involving, primarily, women's digital skills training, both in higher and technical education as well as in continuing education. This would allow women to fully participate in every aspect of life, society and the economy, and would contribute to ensure a minimum level of digital skills even in low-skilled jobs. These skills enable innovation in a digital economy to flourish, but also support the infrastructure that firms, governments, commerce and users rely on (OECD, 2015c).

Likewise, policy design and implementation are pivotal to bridge the digital gender divide. They may offer "leapfrog" opportunities for all women, also women in trade and in businesses

- including in small and medium enterprises (SMEs) - and enhance access to knowledge and employment opportunities, thus boosting economic growth and fostering greater gender equality and inclusiveness for all.

In turn, a number of societal, economic, technological and political trends are shaping education, its organization, its content and the way it is delivered, and ultimately education's ability to fulfill its own mission, i.e. to form individuals, and help them develop as persons, citizens and workers. In addition, demographic trends such as the aging of the population, coupled with the speed, scale and scope of the changes brought about by the digital transformation, call for a careful rethinking of education, on a number of dimensions. These include rethinking formal and informal learning and understanding to how to make of education the lifetime helpful companion of individuals, in an effort to foster inclusive growth and inclusive societies (OECD, 2019a).

These megatrends are accompanied by high expectations for education. Among them, managing to provide better education for more people and education being key to address increased economic and social inequalities and divides, including the digital gender divide.

The report on "The role of education and skills in bridging the digital gender divide – Evidence from APEC economies", produced by the OECD with the support of Chile in the context of the Asia-Pacific Economic Cooperation (APEC), explores the root causes of the gender digital divide; the demands of the workforce for digital skills of women; the skills needed to succeed in the digital transformation and what this implies for women; and the role of education on building skills for the digital era and bridging the digital gender divide. The report further proposes an education-centered future-looking strategy which identifies existing evidence relevant to bridging the digital gender gap and outlines possible actions in support of policymaking aimed to narrow the digital gender divide in APEC economies.

The report proposes a multifaceted approach and is articulated around the following key areas of analysis:

1. The digital gender divide in APEC economies: understanding its root causes

Chapter 1 discusses the root causes of the digital gender divide and provides evidence about a number of stylized facts. These encompass: hurdles to access and affordability, education and technological literacy (or lack thereof), skills, attitudes and expectations, online safety, time poverty as well as inherent biases and socio-cultural norms, with a special focus on APEC economies. Stereotyping and role models contribute importantly to gender segregation in different fields of study and work and to lower the self-confidence of girls in general, and in particular in mathematics. This leads to lack of women in science, technology, engineering, and mathematics (STEM)–related fields, including in information and communication technologies (ICT). Education systems should not only aim to endow all individuals, and girls and women in particular, with the skills needed in the digital era, but should also help infuse more confidence in girls, for them to feel comfortable in any domain.

The chapter further provides evidence about the role that education can play in bridging the digital gender divide, especially in the context of the Fourth Industrial Revolution.

2. Skills for the digital era

Chapter 2 analyses the effects of digitalisation on skills demands and the future of work. It sheds light on the skills that may help women narrow gender gaps (including the gender pay gap), especially in digital intensive sectors. It further provides evidence about the bundle of skills and, hence, the complementarity between different skills, that appear to be important to succeed in the Fourth Industrial Revolution, and about gender gaps in problem solving in particular. First-time estimates of gender differences in occupational mobility, and the possibility for women to move to different occupations if made redundant by automation are finally proposed, to inform the discussion about the role of education and training in facilitating participation and resilience on the labour market.

3. Thriving in the digital era: The importance of education and curriculum design

Chapter 3 provides evidence about the importance of early interventions to bridge the digital gender divide, with a particular focus on digital literacy and digital skills. It also outlines some of the key challenges faced by girls and women, with a view to identifying skills and competence needs that should be taken into account when (re)designing education and training curricula. The aim is to inform APEC economies' discussion on the possible strategies that could be promoted and developed in education, in a view to making education systems more inclusive and able to better prepare students for the future.

4. What role for policy? Main conclusions and policy implications of the analysis

Chapter 4 concludes and discusses the possible role of policy, as emerged from the analysis in the other sections. It compounds the key policy lessons, implications and recommendations that policy makers may consider implementing in APEC economies and beyond to bridge the gender digital divide.

Chapter 1

THE DIGITAL GENDER DIVIDE IN APEC ECONOMIES: UNDERSTANDING ITS ROOT CAUSES

This chapter discusses the root causes of the digital gender divide and provides evidence about a number of stylised facts, with a special focus on APEC economies.

The analysis encompasses: hurdles to access and affordability; education and technological literacy, or lack thereof; skills; attitudes and expectations; online safety; time poverty; and inherent biases and socio-cultural norms.

The chapter further provides evidence about the role that education can play in bridging the digital gender divide, especially in the context of the Fourth Industrial Revolution.

Addressing lack of access, skills, time and safety: breaking the “pillars” of the digital gender divide

Women and men are not equal when it comes to accessing digital technologies such as mobile phones and the Internet, nor in terms of the knowledge needed to use them[1].

The root-causes of this gender-based digital divide are diverse. Among the most important there are: hurdles to accessing digital technologies, unaffordability of digital means, lack of (digital) education and technological literacy, online safety and security concerns, time poverty as well as inherent biases and socio-cultural norms.

Understanding the breadth and depth of such causes in the economies member to the Asia-Pacific Economic Cooperation (APEC) is key for the design of policies aimed to tackle and overcome the digital gender divide in the context of the Fourth Industrial Revolution.

Access and affordability

Digital gender gap in Internet and software usage[2] in APEC economies

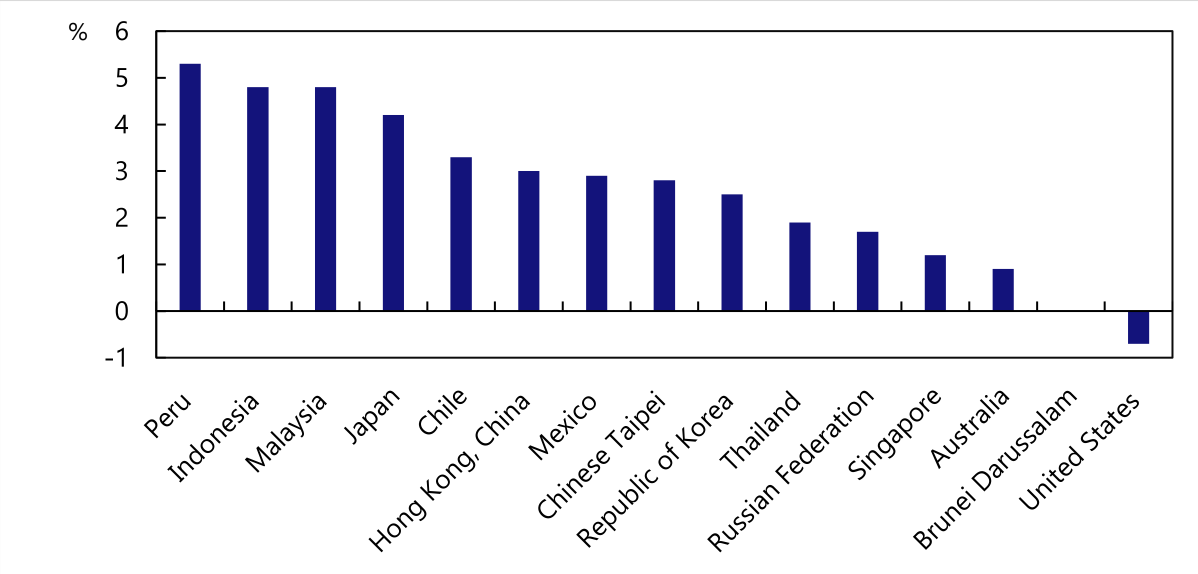
Worldwide, around 250 million fewer women than men are online (ITU, 2017). While the global digital gender divide in Internet usage remained essentially unchanged (passing from about 11% in 2013 to roughly 12% in 2017), the patterns observed are worrisome as they point to increased inequality in Internet use between developed and developing economies (OECD, 2018b).

In 2018, in all APEC economies but the United States, women were found to use the Internet to a lesser extent than men. The widest digital gender divide could be observed in Peru; Indonesia and Malaysia, where women were found to be less likely than men to use the Internet from any location (by 5.3%, 4.8% and 4.8%, respectively. See ITU, 2019). Data conversely indicate that in 2017 women used the Internet to about the same extent in Brunei Darussalam (ITU, 2019).

[1] The term "digital divide" refers to the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities (OECD, 2001).

[2] Measured as the number of women/men using the Internet, as a percentage of the respective total female/male population. The gender gap represents the difference between the Internet user penetration rates for male and female individuals.

Figure 1. Digital gender divide in Internet usage in selected APEC economies, 2018



Notes: Data for Australia, Chinese Taipei, Chile, Hong Kong (China) and Japan refer to 2017; data for the United States refer to 2015. Data are missing for Canada, China, New Zealand, Papua New Guinea; the Philippines; and Viet Nam.

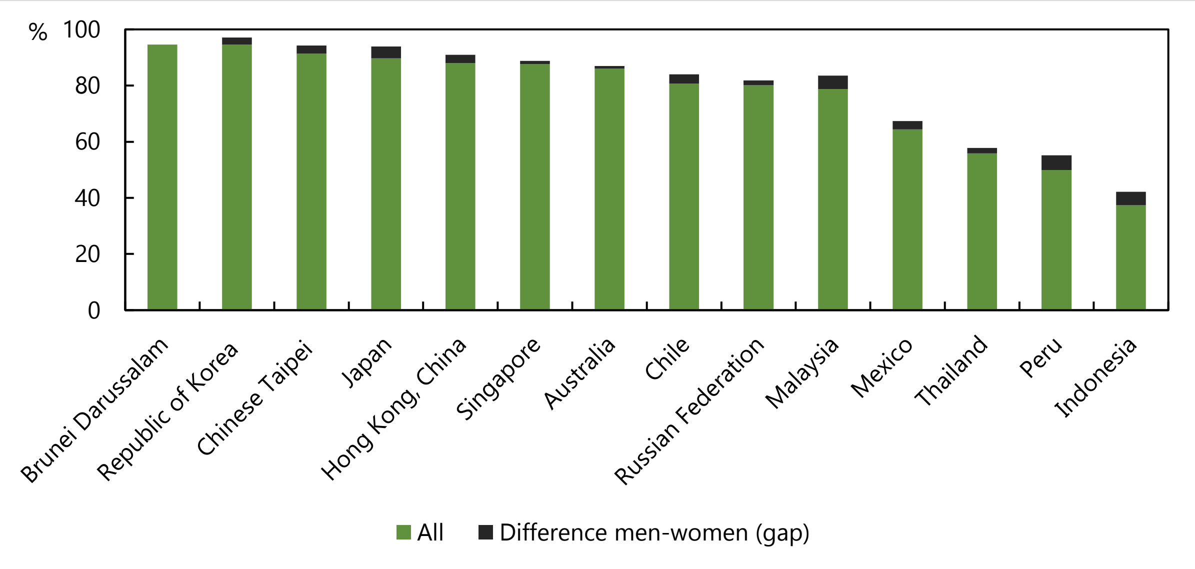
Source: ITU (2019), World Telecommunication/ICT Indicators Database, Gender ICT Statistics, https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx; ITU (2018), World Telecommunication/ICT Indicators Database, Gender ICT Statistics.

Figure 2 shows that while total Internet usage differs importantly across those APEC economies for which data are available, in general men are more likely to use the Internet than women.

Men and women not only differ in the extent to which they use the Internet, but also with respect to what they do online, e.g. whether they purchase and sell online, make video calls, apply for jobs online, use online banking services or use social medias to network. Data from the OECD ICT Access and Usage by Households and Individuals Database (2019) shows that women look for or apply online for jobs less than men (by about -9 % in Chile and -5% in Mexico). Patterns are conversely very similar in the USA and the Republic of Korea, where slightly more women (about 1% more) look for or apply for a job online.

When it comes to the patterns of Internet usage over time, gaps appear to have decreased in some economies, and increased in others. Such gaps should nevertheless be seen in relative terms, i.e. in relation to the total share of Internet usage by individuals in an economy.

Figure 2. Individuals using the Internet in selected APEC economies, 2018 (in %)



Notes: Data for Australia, Chinese Taipei, Chile, Hong Kong (China) and Japan refer to 2017. Data are missing for Canada, China, New Zealand, Papua New Guinea; the Philippines; and Viet Nam. Data for the United States, which refer to 2015, are not displayed in Figure 2.

Source: ITU (2019), World Telecommunication/ICT Indicators Database, Gender ICT Statistics, https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.

The digital gender gap is also evident with respect to Internet banking: women use less Internet banking services in Mexico and Chile by 3% and 10%, respectively. In contrast, women in the United States are more likely to rely on Internet banking than men (by 2 %).

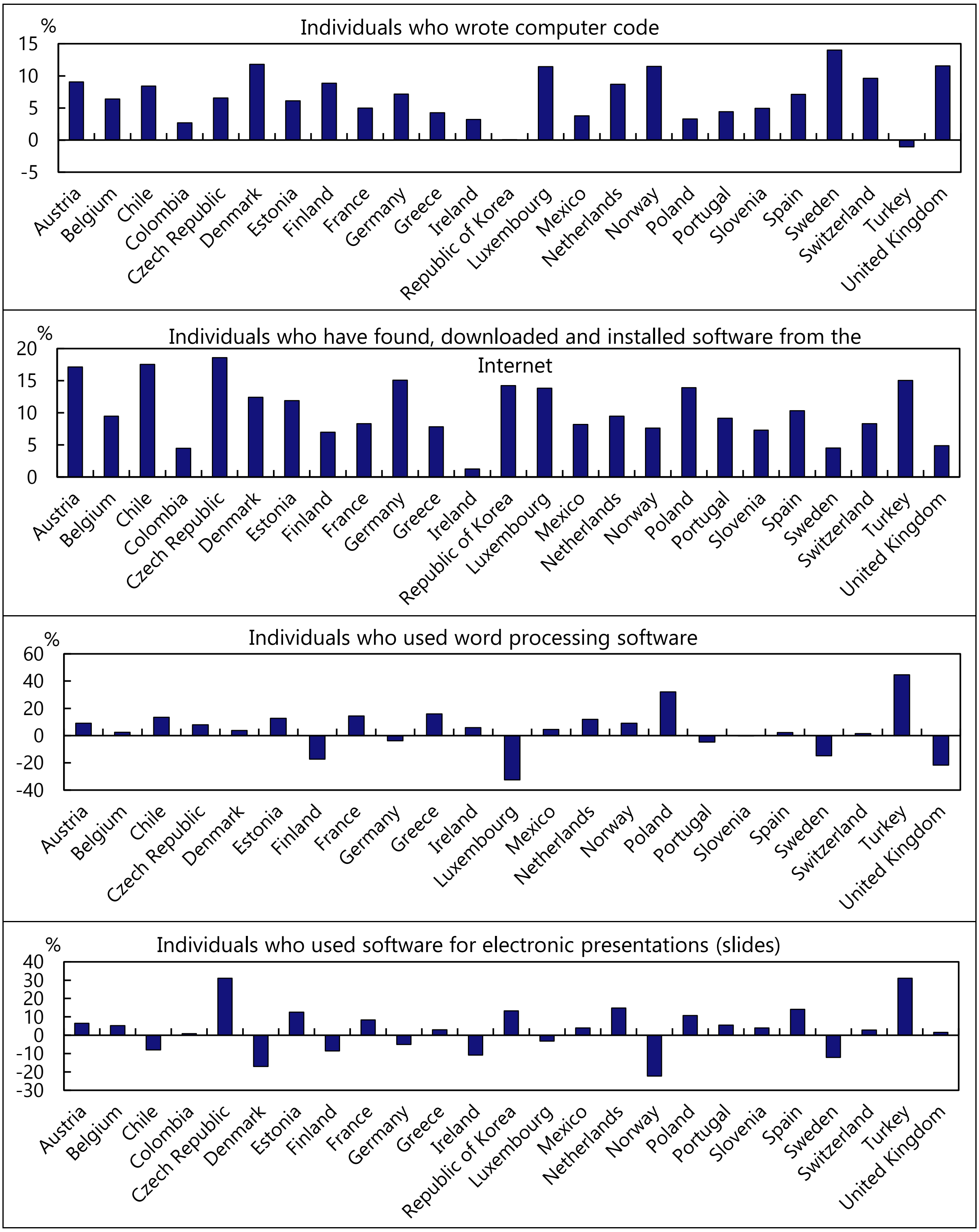
Women not only use the Internet less than men, but also use and develop less software applications. This is especially worrisome since this means that women are not contributing as they should to shape digital means and to build a digital future that accounts for women's needs and desiderata.

Figure 3 shows the gender gap in software use or development in Mexico; the Republic of Korea; and Chile and non-APEC economies (e.g. writing a computer code, downloading and installing Software from the Internet, using software for word processing and electronic presentations).

These data about the gender gap in Internet usage are consistent with further evidence from Latin America (Gray et al., 2017) and Singapore (Ji and Skoric, 2019), where male users are reported to use the Internet proportionally more for research and (political) information gathering, in comparison to women. The latter tend to use the Internet relatively more for socialising and as a means of relationship maintenance, in addition to participating in online commerce (Gray et al., 2017; Ji and Skoric, 2019).

Figure 3. Gap in specific Internet usage, 2017 (last 12 months)

APEC economies for which data are available and selected OECD countries



Notes: Data for "Individuals who have used word processing software - last 12 m (%)" are not available for the Republic of Korea. The gap is measured as the number of women/men conducting the online activity, as a percentage of the respective total female/male population. The gender gap represents the difference between the specific online activity rates for male and female individuals.

Source: OECD (2019d), ICT Access and Usage by Households and Individuals database, https://stats.oecd.org/.

Age and the digital gender divide

Age further appears to play an important role in shaping the digital gender divide in Internet usage. While fewer elderly women (between 55 and 74 years old) use the Internet compared to men, the digital gender gap in Internet usage decreases in the case of middle-aged (between 25 and 54 years old) or young women (16-24 years old).

For example, data about the 2017 shows that older Korean and Mexican men are respectively 7 and 3 percentage points more likely to have used the Internet during the past year as compared to women in the same age group. In other non-APEC economies, as for example in Austria, Germany, Greece, Italy and Turkey, the gender gap for the older age group is 13, 14, 13 and 13 percentage points, respectively. Conversely, middle-aged women in Chile and the Republic of Korea are seemingly equally likely to have used the Internet within the last 12 months. In other economies, while the gap is not bridged yet, it is nevertheless shrinking. For example, middle-aged women in Mexico are 1 percentage point less likely than men in the same age group to have used the Internet during the past year (OECD, 2019d).

Differences in Internet use by age group nevertheless exist among economies. For example, young women and girls (16-24 years old) are less likely than boys and men to use the Internet in Chile and Mexico (by 1 percentage point, and 2 percentage points, respectively). In contrast, young women tend to use the Internet more than young men in Japan (by around 1 percentage) and use it as much as young men in the Republic of Korea (OECD, 2019d). Socio-cultural norms, biases and safety concerns may contribute to explain these patterns and are discussed in sections that follow.

Digital gender gap in the ownership of mobile phones and use of mobile Internet

Mobile phones are one of the most far-reaching technologies in history but not every woman worldwide can enjoy its benefits.

Worldwide, mobile phone subscriptions recently reached over 5 billion (GSMA, 2018). Projections for the future suggest that mobile subscriptions are likely to further increase and approach 6 billion by 2025 (GSMA, 2019). However, women in low- and middle-income economies are on average 10% less likely to own a normal mobile phone than men, resulting in 184 million fewer women owning mobile phones than men (GSMA, 2018).

Smartphone subscriptions are increasing worldwide, too. For most of the world's population, mobile is the primary way to access the Internet (ITU, 2017). In 2018, close to 3.3 billion people had subscribed to mobile Internet services (GSMA, 2018). Within the next eight years, more than 1.4 billion people are anticipated to use mobile Internet, which is equivalent to a growth of 1.6 times (GSMA, 2019).

An important part of the increase in smartphones usage takes place in the Asia Pacific region, resulting in growing mobile data usage. By 2025, half of the forthcoming expected growth of new subscriptions is anticipated to come from there: the use of smartphones in the Asia Pacific region is expected to increase to 60% of the total population, resulting in 359 million subscriptions in the region (GSMA, 2019). Among all APEC economies, China (8%); Indonesia (3%); and the USA (3%) are expected to account for the biggest share of new subscribers by 2025 (GSMA, 2019). This development goes hand in hand with mobile data usage. This is expected to grow in the Asia Pacific region between 2018 and 2024 by 800%, spurred by increased smartphone adoption and availability of affordable high-speed networks (GSMA, 2019).

However, not all members of society have access to these technological developments and innovations and are able to benefit from them. This is unfortunately true for women.

The gender gap in mobile Internet use is considerably wider than the gender gap in mobile ownership, although differences exist between economies as well as between rural and urban areas. Overall, in the world, the GSMA (2018) estimates that women are 26% less likely than men to use mobile Internet services. This equates to 327 million fewer women using mobile Internet than men (GSMA, 2018). While mobile phone ownership is basically the same for men and women in China, women are 4% less likely to use mobile Internet. In Mexico, women are about 5% less likely to own a mobile phone and 10% less likely to use mobile Internet.

Moreover, women in rural and urban areas use mobile phones and mobile Internet to a different extent. For example, in China, more women in urban areas have mobile phones than men; while men and women in rural areas are equally likely to own a mobile phone. Despite ownership, though, women in urban and rural areas use mobile Internet less than men, by 3% and 4%, respectively (GSMA, 2018).

Gender differences also emerge when considering the amount and types of mobile Internet services. Women tend to use less and different services than men. For example, in Mexico, women use functions as video calling by 6 % more than men; however, they are 7 % less likely to browse the mobile Internet. Similar gaps emerge from data for China (GSMA, 2018).

Digital gender gap in affordability of mobile services

The possibility to afford owning a mobile or to subscribe to a basic Internet connection remains one of the most significant hurdles for women in their quest for digital parity. Around the world, over two billion people live in economies where even only 1 GB of mobile data are unaffordable. This is particularly relevant in low- and middle-income economies, where 1GB of data costs over 5% of a monthly salary – which is above the affordable threshold of 1GB of data priced at 2% or less of average income (A4AI, 2018).

Hurdles to affordability are particularly severe for women. A strong and negative correlation emerges between women's education and income levels and the gender gap in mobile ownership and use of (mobile) Internet. In other words, where female educational attainment and income are relatively lower, and are especially so relative to the costs of mobile handsets or digital devices more generally and the cost of data, the gender gap tends to be larger.

For example, research found that women, often not being the primary household earner, are more likely to own more basic mobile phones and less likely to use the Internet than men (GSMA, 2015). In the Philippines, around 30% of women (versus around only 20% of men) who are aware of mobile Internet identified the cost of both handsets and data as key barriers to using mobile Internet (GSMA, 2018).

Skills, time poverty, and inherent biases and socio-cultural norms

The digital gender divide, affecting women of all ages and across international boundaries, has many underlying causes, which are deeply rooted in society. These include: lack of or low digital literacy, which leads to less confident use of digital technologies; time poverty, which hinders studying; the affordability of access to digital technologies (discussed above); security and safety concerns (discussed below) and inherent biases and social norms. Those causes are often interrelated and affect each other.

Inherent biases and socio-cultural norms contribute to lower self-confidence and motivation, and to cause time poverty

Socio-cultural norms engrained in many parts of society contribute to fuel the gender gap. Even in the digital era, textbooks remain core means of teaching in classrooms and while they could promote equitable attitudes, they often continue to convey discriminatory gender norms and practices. These can lower girls' engagement in classrooms and limit their expectations in education and in life, and stigmatise young girls, thus leading to lower self-confidence (Benavot and Jere, 2018). There is evidence that girls and women are often under-represented in textbooks and curricula; and both genders are shown in highly stereotyped household and occupational roles, with stereotyped actions, attitudes and traits. For example, studies of Chinese pre-primary and primary textbooks show that men are disproportionately represented, while females appear frequently only in reading materials for very young children (Benavot and Jere, 2018).

In Australia, a study carried out in 2009 found that 57% of the characters in textbooks were men. There were double the amount of men portrayed in law and order roles, and four times as many depicting characters engaged in politics and government (Lee and Collins, 2010). Another study found that social studies books in China depict scientists and soldiers as male while teachers and three-quarters of service personnel were female (UNESCO, 2007). In India, on average, in the six mathematics books used in primary schools, men dominate activities representing commercial, occupational and marketing situations, while no single woman is depicted as an executive, engineer, shopkeeper or merchant (Benavot and Jere, 2018).

Biases in the form of parents still holding different expectations for their sons and daughters, particularly about the roles they expect for their daughters (as not being the main bread winner) versus their sons, can further lead to role modelling and stereotyping, and infuse less self-confidence in girls. Importantly, while such gender differences in self-confidence emerge early in life, they can persist at later stages. OECD work (2015d) showed that in all OECD countries and economies that participated in a parents-related questionnaire, parents were more likely to expect their sons, rather than their daughters, to work in a STEM field. This is not due to the higher average performance of boys in mathematics, since disparities in parental expectations occur even when comparing boys and of similar performance in mathematics.

Digital (il)literacy stems from lack of (digital) education

Lack of education results in lack of skills and confidence and represents a key barrier to the access and use of digital technologies and of mobile technology. Lack of education, also technical education, does not only impinge upon individuals' ability to understand the possible benefits of digital technologies but may also lead to technical illiteracy, and to anxiety with respect to computers and to digital tools and technologies more generally. Such "technophobia" is often a result of concurrent factors including education, employment status and income level (OECD, 2018b).

"Technophobia" appears to be deeply rooted in the socialisation patterns of boys and girls. Girls and women are much more likely to experience computer anxiety than boys and men. While boys see computers often as toys, the computer anxiety of girls is often a result of gender stereotypes, which leads to gender differences in computer attitudes and computer performance. As such, girls and women who suffer from computer anxiety can be at a disadvantage when learning other material with the aid of computer-assisted software (Cooper, 2006).

Girls, who are less likely to gain the same school education than boys, are also less aware of the potential benefits that the Internet may bring. This is particularly the case in developing economies. Women are 10-11% less likely than men to be literate in Papua New Guinea and Peru, and around 5-6% so in China; Indonesia; and Malaysia, respectively[3] (UN, 2019). Similarly, women in those socio-economic contexts are found to be less aware of the benefits of using a computer or a mobile phone. As such, women have more often the perception that owing a mobile phone or using the mobile Internet is not relevant to their lives because they think they "do not need it" (Fallows, 2005). For example, in Mexico, 42% of women who do not own a

[3] Data are for 15-year olds and older, data from 2007-2011.

mobile phone believe that mobile phones are not relevant for them, compared to only 24% of men (GSMA, 2018); in China, this is the case for 44% of women (versus 34% of men).

Even when women know about digital technologies, they are found to be less confident in actually using them. For example, in Indonesia, 34 % of women (versus 22% of men) do not use a mobile phone because they say that they do not know how to use one. When it comes to mobile Internet, women are less aware than men about it or do not know how to access it. For example, in Mexico and China, 31% of women (versus 15% of men) who use mobile phones are not using mobile Internet because they do not know how to access it (GSMA, 2018).

Particularly in developing economies and in traditional environments in rural areas, women and girls further face persistent structural constraints, including their higher probability to be out of school than boys - their likelihood is twice as high as girls in urban areas. In rural areas, women and girls generally work more in agriculture, and their work is often unpaid or considered as a contribution to the family. When employed, women in rural areas tend to have shorter term and more precarious jobs and are generally less protected than men in rural areas or people living in urban areas (UN Women Watch, 2018). This ultimately translates in being confined in technology-poor environments where it is difficult if not impossible to use digital technologies, and into having scarce (if any) resources, also financial ones, to be used to go online (OECD, 2018b).

The challenges that women face in the formal economy are replicated and augmented in the informal economy. This often means, among others: occupational segregation, gender wage gaps, unequal access to resources and social protection, disproportionate burdens of unpaid care and domestic work, violence and harassment and even greater barriers. Paid domestic work, home-based work, street vending and waste picking are all sectors dominated by women, and they also tend to be the most vulnerable and precarious forms of informal employment. Women make up for more than 80% of homeworkers (industrial outworkers) and 83% of the world's 53 million domestic workers. Globally, 57% of domestic workers (29.7 million individuals) have no limitations on their working hours (UN, 2017).

Lack of understanding of other languages, which represent another aspect of low or lack of literacy, can further hinder the uptake of the Internet and its usage, especially in regions where a proportionally important part of the population is illiterate. Automatic translations of mobile content in local languages represent one way to at least partially overcome lack of literacy and language barriers. A recent report by GSMA (2019) highlights that significant improvements in terms of content and service provision, including the generation of more mobile content in local languages, have been made in this regard in APEC economies as Singapore; the Republic of Korea; and Hong Kong, China (GSMA, 2019). This was achieved through developments occurring outside the tech hubs located in North America and Europe. In 2017, 35% of all mobile applications were developed outside of North America and Europe, and 25% were from low- and middle-income economies (up from 28% and 15% respectively in 2014) (GSMA, 2019).

But more work would need to be done in APEC economies featuring important literacy gaps (UN, 2019). For example, in China, 37% of women (versus 22% of men) who use a mobile phone identified reading and writing difficulties as barriers to using mobile Internet (GSMA, 2018).

Finally, location matters also for education and skills. The gender gap tends to be larger in rural areas of developing economies. For girls in rural areas, the likelihood to attend school is only half the one of girls living in urban areas. Women and girls in rural areas are much more likely to work in agriculture. Their work is often unpaid or considered as a contribution to the family. When employed, women in rural areas also tend to have relatively shorter-term contracts and more precarious jobs. They are also generally less protected than men in rural areas or compared to people living in urban areas (OECD, 2018b).

Time poverty jeopardises paid work, studies, rest and leisure

Time poverty is another crucial reason for gender-related (digital) exclusion. Time poverty results, among others, out of unpaid work as household work and care for children and the elderly. This translates into lack of enough time for paid work, studies, rest and leisure (Davy et al., 2018).

There is consistent evidence that worldwide women are particular prone to time poverty. For example, in Asia, evidence from China (Qi and Dong, 2018) shows that workers who are women, low-paid, married, and who live with children or the elderly in counties with higher overtime rates and lower minimum wage standards are more likely to be time poor. Also in the USA, the marital status of women differentiates housework, leisure, and sleep time (e.g. married mothers do more housework and sleep less than never-married and divorced mothers) but does not influence the amount of time that mothers dedicate to childcare[4] (Pepin et al., 2018). In Latin America, female coffee producers in Mexico are found to experience time poverty due to domestic burdens, which limit their ability to fully participate in coffee organisational governance. This is problematic as it limits women's ability to gain valuable skills, including digital, business and leadership skills, and to develop and implement activities that can enhance gender equity (Lyon et al., 2017).

[4] Various studies confirm a positive association of marital status with housework: partnered women are likely to do more housework relative to unmarried women. Once married, if women transition into motherhood, their household and care work seem to increase, while fathers' household work seems to reduce, even among couples with egalitarian patterns before the birth of the child (Baxter et al., 2008; Grunow et al., 2012; Gupta, 1999; Sayer, 2016). This pattern seems to be relevant even for married mothers with greater work hours and higher earnings relative to their husbands (Hook, 2017).

The burden of housework and care work also falls on women and girls in developing economies in Asia and Pacific, which limits their participation in study, paid work, or social and political activities, both online and offline. Improved infrastructure – including water supply, electricity and access to sanitation – can help to reduce the time spent on housework and care work, although it does not seem to be able to impact the gender division of labour in the household[5] to the extent needed to move to greater gender parity (ADB, 2015).

In every region, women spend more time in unpaid care work than men, ranging from 1.7 times more in the Americas, 2.1 times more in Europe and Central Asia, 3.4 more in Africa, 4.1 times more in Asia and the Pacific, to up to 4.7 times more in the Arab States. Worldwide, on average women perform 76.2 % of total hours of unpaid care work, which equals more than three times as much as men. Evidently, this leaves women less times to grow in their careers or in any of their aspirations, and is generally accompanied by lack of social protection (ILO, 2018; UNSD, 2017). Women are overrepresented among the 73 % of the world's population that has partial or no access to social protection, participate less in the labour market, earn lower wages and enjoy less access to credit and assets than men. They therefore have less access and lower coverage with regard to contributory social protection instruments, such as pensions or unemployment compensation and even health insurance. Globally, the proportion of women above retirement age receiving a pension is on average 10.6 percentage points lower than that of men (ILO, 2018).

In addition to carrying out more unpaid work, women work more hours than men when unpaid care work and paid work are added together. This makes women consistently time poorer than men. The women–men ratio of total work (paid and unpaid) ranges from 1.05 in the Americas, 1.11 in Asia and the Pacific and Europe and Central Asia, 1.19 in Africa, up to 1.25 in the Arab States. In Asia and the Pacific region, men perform the lowest share of unpaid care work of all regions (1 hour and 4 minutes). When both work for pay or profit and unpaid care work are accounted together, the working day is on average longer for women (7 hours and 43 minutes) than it is for men (6 hours and 57 minutes) (ILO, 2018).

Time poverty is especially critical when it comes to studying. Working while studying may compromise academic performance, and may negatively influence whether and how students achieve some needed skills, as well as the competences and knowledge required for a profession (Burston, 2017). Especially students with preschool-aged children have a significantly lower quantity and quality of time for college than comparable peers with older children or no children at all (Wladis et al., 2018).

[5] For example, electricity tends to reduce the amount of time spent on housework and care work, and has the potential to increase the amount of time women spend on paid work. However, improved water supply, which can reduce the time women spend doing burdensome unpaid work, seems to have little impact on the gender division of labour in the household (ADB, 2015).

As such, greater availability of convenient and affordable childcare (e.g. increased on-campus childcare, revised financial aid formulas that include more accurate estimates of childcare costs) appears to be particularly important for student mothers to be able to focus on their education (Wladis et al., 2018).

Inherent biases and socio-cultural norms persist despite girls' educational attainment and performance

Inherent biases and socio-cultural norms and stereotypes are another barrier to women's equal use of information and communication technologies (ICT) and to their participation in the (digital) economy more broadly. This happens despite girls' and young women's educational attainment and performance (obviously, conditional on participation in education in the first place, as girls are less likely to gain the same school education than boys).

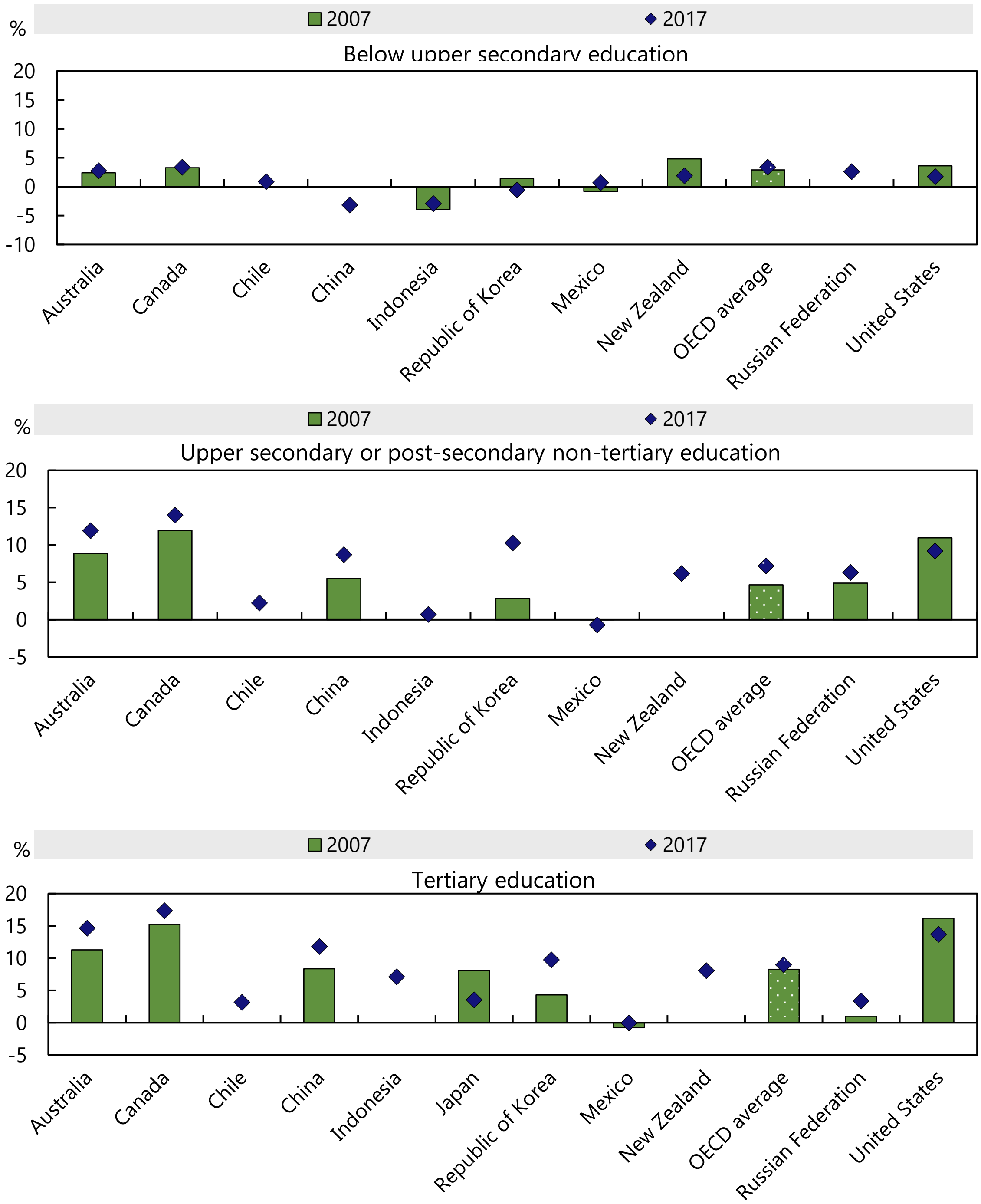
Interestingly, when both girls and boys have access to education, in most of the economies for which data are available, female students are more likely to complete education and to obtain better graduation rates than male students. This is generally true for the whole higher education system, from the final stage of secondary education up to tertiary education.

Over time, this relatively better performance of girls has become even more marked, as can be seen in Figure 4. Notable exceptions emerge in the case of below upper secondary education in China and the Republic of Korea: in 2017, male students were more likely than female students to complete such studies, and the situation worsened in the Republic of Korea as compared to the 2007. Such patterns are worrisome for their possible effects on inclusion, as these people, especially women, will not be able to go continue education, nor perform jobs requiring higher education type of qualifications.

Despite achieving better results, female students appear less attracted by STEM subjects, and exhibit higher drop-out rates when pursuing a science, technology, engineering, and mathematics (also known as STEM) degree. There is consistent evidence that in higher education and afterwards, young women are under-represented in the fields of science, technology, engineering and mathematics (STEM). This under-representation is particularly striking when it comes to computer science (OECD, 2017a), despite the good job prospects that these fields of study generally entail.

Figure 4. Likelihood of girls to complete education compared to boys

In % points, 2007 and 2017



Notes: Graduation rates correspond to (girls' rates – boys' rates). Positive number denote graduation rates that are higher for girls than for boys. Diamonds above the bars mean that female students have become even more likely to complete education than boys in 2017 than they were in 2007.

Source: OECD (2018a), Education at a Glance, Table A1.2, https://doi.org/10.1787/888933801620.

Relative ratios vary, but gender equality in APEC economies for which data are available is far from being achieved. The closest to featuring equal shares of men and women STEM graduates is Indonesia, where four out of ten graduates are female, but in New Zealand; the United States; Australia; Canada; Mexico; and the Republic of Korea, only three out of ten graduates in STEM are women; in the Russian Federation; Chile; and Japan the ratio goes down to two out of ten.

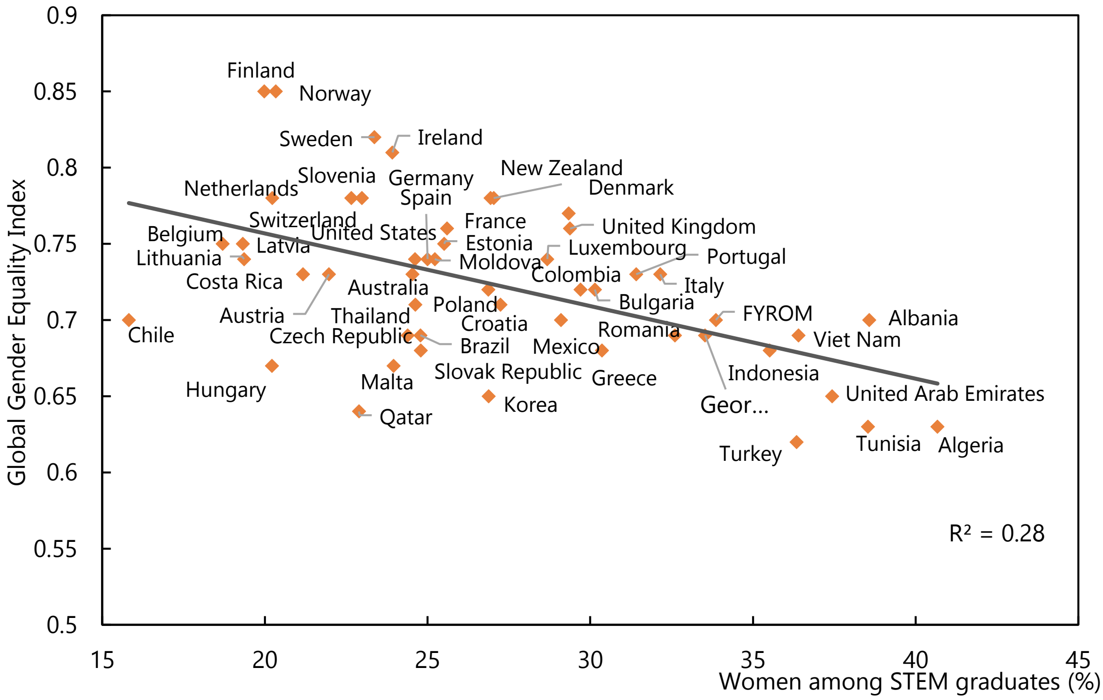
When it comes to doctoral holders in STEM fields, on average, across APEC economies[6], about one third (35%) are women. Men are almost 3.5 times more likely to be a doctoral holder in ICT and almost three times more likely to be a doctoral holder in "engineering, manufacturing and construction". Conversely, women are equally-represented and even over-represented in other – "less-technical" – fields, such as health and welfare and education. Interestingly, the field "health and welfare" requires just as much scientific knowledge as other fields, but generally leads to jobs that could be qualified as "care jobs". For example, the average of all female tertiary graduates in health and welfare is 79%, and 75%, respectively, in APEC[7] and OECD economies. Therefore, the gender gap does not fully correspond to the expected "humanistic-scientific" divide, but rather to what is called a "care-technical" divide (Barone, 2011), which translates in women ending in different types of occupations (OECD, 2018a).

In addition, not all female graduates in STEM make a career in tech sectors, due to the sum of obstacles discussed in this report. OECD work (OECD, 2017a) shows that not only fewer women study STEM disciplines than men, but also participate only at the margins in technological development. For example, three quarters of a popular open-source programming language for data analysis were produced by teams composed of only men. Women-only teams accounted for a mere 6% of software packages, whereas the remaining 17% came out of mixed teams of software developers (OECD, 2018b).

At a first glance it may be easy to assume that gender disparities in participation in STEM simply reflect broader disparities between men and women in labour markets and gender disparities in political representation. Nonetheless, recent evidence on the gender equality paradox suggests that it is precisely in economies with greater gender equality (measured through the Global Gender Equality Index) that females are most severely under-represented among STEM graduates (Stoet and Geary, 2018). Figure 5 illustrates how the average percentage of women among STEM graduates in each of the 67 economies that took part in the PISA 2015 study tended to be lower the greater the economy's performance on the Global Gender Equality Index (WEF, 2015). Across the nine APEC economies with available information only around 27% of STEM graduates were women.

[6] Average calculated based on data from Australia; Canada; Chile; Indonesia; Japan; the Republic of Korea; Mexico, New Zealand; the Russian Federation; and the United States.
[7] Average based on data from Australia, Canada, Chile, Korea, New Zealand and the United States.

Figure 5. Gender equality and gender differences in the percentage of women among STEM graduates



Source: Stoet, G. and Geary, D. C. (2018), "The gender-equality paradox in science, technology, engineering, and mathematics education".

It has been argued that such paradox and the paucity of women training to work in STEM intensive sectors in general and building strong digital literacy more specifically reflects complex and interconnected differences between males and females in competences in different domains, their attitudes and self-beliefs (all aspects that are detailed in the rest of the report).

Girls and women appear to be frequently embedded in cultural or societal environments expressing discrimination or even hate against women, a fact that most fail to perceive, understand or recognise. An example is the misogyny conveyed in the lyrics of hip hop and trap music[8], which teenagers seemingly enjoy and actively participate in, including teenage girls. While misogyny does not characterise all music genres nor rap music as a whole, a sizeable share of rap does contain messages against women, often rather extreme ones (see e.g. Weitzer and Kubrin, 2009, for an overarching analysis)[9].

[8] "Hip hop" or "rap" music is a music genre consisting of stylised rhythmic music commonly accompanied by "rapping", a rhythmic way of speaking or singing. "Trap" music is a type of hip hop music developed in the late 1990s to early 2000s, which takes its name from the places where drug deals take place (called traps).

[9] The entertainment industry also plays a role in such a misogynist culture, by allowing or not censoring sexist lyrics and by rewarding artists who produce them with huge sums of money, awards and spin-off products.

Also, evidence suggests that watching sexual music videos – something that the Internet facilitates - may increase misogynistic beliefs among adolescents over time (see e.g. van Oosten et al, 2015).

Which STEM fields appeal to women?

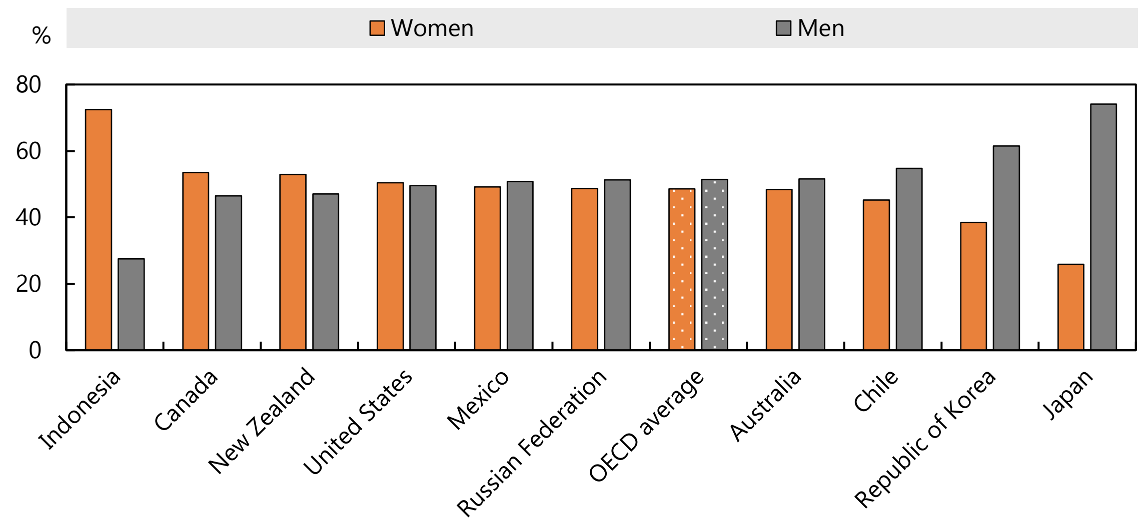
Although differences across economies emerge, interestingly, “natural sciences, mathematics and statistics” appear attractive to women. Gender equality or even relatively higher shares of women emerge in some APEC economies for which data are available (Figure 6). In fact, women are almost equally likely to hold a tertiary graduation in “natural sciences, mathematics and statistics” in Mexico and the United States. Women in Canada; Indonesia; and New Zealand are even more likely than men to be tertiary graduates in “natural sciences, mathematics and statistics”. Indonesia shows a remarkable 72% of female tertiary graduates in “natural sciences, mathematics and statistics”.

While the data above look promising, there still are APEC economies where gender gaps of this type exist, with the largest differences in tertiary graduates in “natural sciences, mathematics and statistics being displayed by the Republic of Korea and Japan (23%, and 48%, respectively).

Women not only seemingly find it hard to enrol in STEM studies, but important differences in study persistence between STEM and non-STEM fields emerge, with women featuring higher drop-out rates or likelihood to switch majors, which translate into lower graduation rates of women in STEM. Although in general no gender differences characterise the probability of graduating in one's initial major choice (Astorne-Figari and Speer, 2018), women who enter STEM majors are far less likely to graduate in the field. They are twice as likely to switch majors. For example, data about Germany reveal that female students in STEM are around 23% more likely to drop out than their male fellow students. It is further observed that gender divergences emerge at later stages of STEM studies, following the 7th semester, which is when students start to orientate themselves towards labour market opportunities (Isphording and Qendrai, 2019).

Figure 6. Tertiary graduates in natural sciences, mathematics and statistics, 2016

As a percentage of tertiary graduates in natural sciences, mathematics and statistics



Source: OECD Education Database, https://www.oecd.org/education/database.htm.

Importantly, switching or dropout decisions are unrelated to poor academic performance (Astorne-Figari and Speer, 2018): if anything, evidence points to female STEM students representing a selected subsample, featuring better high-school degrees and higher scores in personality dimensions such as extraversion and conscientiousness - both of which have been demonstrated to be beneficial for the stability of educational careers (Isphording and Qendrai, 2019).

The low study persistence and overall low graduation rates of women in STEM, the so-called "leaky pipeline" is seemingly due to various biases and socio-cultural norms, which are often economy-specific. These range from gender differences in self-confidence, in college preparation and in the willingness to compete, as well as on the role of teachers and their perceptions of tech industries being male-dominated, among others.

Lack of self-confidence and being risk and peer pressure adverse also disproportionately affects women[10]

There is evidence showing that, already early in life, gender differences in self-confidence emerge, and they persist at later stages. Girls often lack self-confidence, which can be a consequence of parental biases and the different expectations that parents have with respect to their daughters and sons, as well as role modelling and stereotyping.

Parents generally report less ambitious career expectations for their daughters than their sons and, in particular they are considerably more likely to expect their sons than their daughters

[10] More analysis related to perceptions and environmental pressure is provided in the section entitled "The role of education and the environment".

to pursue a career in STEM fields even when comparing boys and girls of similar ability and achievement in mathematics and science (OECD, 2015d). By failing to support and promote ambition among girls, many parents contribute to girls' lower levels of self-confidence, especially in areas that do not conform to stereotypical notions of femininity.

On average, at the age of 15, boys are more than twice as likely as girls to expect to work as scientists or engineers. Actually, less than 0.5% of girls would like to be working in the ICT sector, while this percentage increases to 5% for boys (OECD, 2018b). Differences in performance in scientific and ICT-related fields do not stem from innate differences in aptitudes (OECD, 2015d).

In fact, 15-year old girls' attitudes and lower self-confidence in their own capabilities are often due to external biases and expectations. Girls are less confident in their maths, science and IT abilities, at times due to or fuelled by societal and parental biases, and parents' expectations about the future of their 15-year-old boys and girls – independently of performance in mathematics. This ultimately leads to girls' self-censorship and lower engagement in science and ICTs (OECD, 2018b).

Interestingly, biases and the way women and girls respond to them are economy-specific. Evidence shows that the gender gap of graduates in natural sciences, engineering and ICTs (NSE & ICT) is smaller in economies with higher life-quality pressure, and bigger in economies featuring more gender equality. In other words, in a context with fewer economic opportunities and higher economic risks, female students may be more attracted to relatively high-paying STEM occupations compared to environments with relative greater professional opportunities (Stoet and Geary, 2018).

Related to that is the higher risk aversion of girls and women (Niederle and Vesterlund 2007), which can arise very early in life and remain throughout (Sutter and Glätzle-Rützler 2015), and the effect of peers in STEM classes. When the study environment is perceived as more competitive (e.g. because of a higher share of male students), female persistence in STEM is lower compared to non-STEM. Also, women enrolled in classes featuring higher ability peers are less likely to graduate with a STEM degree, while men's persistence remains seemingly unaffected by such pressure. Women in male-dominated STEM fields are more likely to be discouraged by low relative performance (compared to males) and to switch fields in response (Kugler et al., 2017). The effect is largest for women in the bottom third of the ability distribution (Fischer, 2017). Overwhelmingly, females seem to avoid the culture of STEM rather than science itself, choosing thus more female "intensive" subjects (Astorne-Figari and Speer 2018).

The importance of education and teachers, and of family and social acceptance

First decisions about enrolling STEM fields-related education are already taken during the course of primary education (e.g. middle school). The lower female participation rates in subjects as maths and physics, and the accordingly weaker foundations in STEM-related fields prior to tertiary education may contribute to explain the low female persistence in STEM during university studies (Isphording and Qendrai, 2019). Research suggests that college preparation accounts for two-thirds of the gender differences in choice of science majors, and that it explains about a quarter of differences in switching out of science majors (Speer, 2017).

Furthermore, teachers and professors can play an important twofold role in (female) students' career decisions. Teachers and professors can act as powerful role models for their students, but their teaching style might reflect underlying gender-biased stereotypes (Isphording and Qendrai, 2019). Professors' gender has a powerful causal effect not only on female performance in STEM-intensive courses but also endurance and graduation in STEM majors (Carrell et al., 2010). Research shows that girls and young women can develop a self-perception of belonging to the STEM culture and are more motivated to pursue such studies in the presence of female role models/professors/experts (Dasgupta and Stout, 2014). Self-perception might be further aggravated by teachers' personal gender stereotypes. Teachers with more marked gender stereotypes generate larger gender gaps in students' performance in mathematics, which, in turn, affects the choice of majors in STEM or not (Carlana, 2018).

Social acceptance from family members is also found to be crucial for girls and women to be actively engaging in the digital domain, and to pursuing educational and professional opportunities in technological fields (Vadillo et al., 2012). Active female Internet users are three times more likely to have families who are "very supportive" of their Internet use, whereas female non-users are six times more likely to be exposed to family opposition (Intel and Dalberg, 2012). Such family hurdles can range from lack of support to outright discouragement or even prohibition.

Self-beliefs have an impact on skill development because they determine how well students motivate themselves and persevere in the face of difficulties. They influence students' emotional life, and influence the choices students make about coursework, additional classes, and even education and career paths (OECD, 2015d). Evidence from PISA indicates that girls report consistently holding less positive beliefs in their own abilities in mathematics and science than boys and are considerably more likely than boys to express feelings of stress and anxiety towards mathematics – even when they perform just as well as boys. Some studies have found that girls rate their own ability as lower than that of boys as early as the first year of primary school– even when their actual performance does not differ from that of boys (OECD, 2015d).

PISA results showed while girls, in general, have lower levels of self-efficacy than boys in both mathematics and science, the difference is much wider in mathematics than in science, and the gender gap in feelings of confidence depends greatly on the type of problem or situation boys and girls encounter. Gender differences in science self-efficacy are smaller or even inverted, with girls reporting greater confidence, when scientific issues are framed in the context of health problems. The same pattern is observed in students' mathematics self-efficacy. Gender differences in self-confidence are particularly large when considering the ability to solve applied mathematics tasks that have gender-stereotypical content. For example, across OECD countries, 67% of boys but only 44% of girls reported feeling confident about calculating the petrol-consumption rate of a car, and 75% of girls (compared to 84% of boys) reported feeling confident or very confident about calculating how much cheaper a TV would be after a 30% discount. However, no gender differences in confidence are observed when students were asked about doing tasks that are more abstract and clearly match classroom content, such as solving a linear or a quadratic equation (OECD, 2015d).

Several studies indicate that the tech industry is a male-dominated sector and women face several biases in all stages of their professional development (Isaca, 2017). For example, women working in the tech sector are more likely to work part-time, take a break from their careers, or even resign (Lamolla and González Ramos, 2018)[11]. Furthermore, women currently hold 21% of the high executive positions in the technology sector (Isaca, 2017), while they represent only 13% of the highest positions in the engineering field (EU COM, 2015). Of all ICT patents, 88% have been registered by all-male teams, and women are paid between 18% to 22% less than men (Ashcraft, McLain and Eger, 2016). Although such inherent biases are (unfortunately) not new, they seem to be hard to dismantle.

The supposed "masculinity" of technology and the "glass ceiling"

Another explanation that has been proposed to explain the digital gender divide is the connection between masculinity and technology (Tiainen and Berki, 2019), which is a result of the historical and cultural construction of gender (Wajcman, 1991). In girls' minds, technologies are thought to be largely male-centric, reinforcing the idea and the social norms that still define technologies to be mostly in the purview of men (Antonio and Tuffey, 2014; Harding, 1986; Lie, 1995). For example, research shows that when fairly recent descriptions of men with computers are made, the frame of reference included engagement of 'superior knowledge' and 'intellectual capacities' as well as 'mastering' and 'power' that may strengthen a man's masculine image. Conversely women with computing science knowledge and computer skills were associated to 'typewriting' and 'office work' (Lie, 1995). For example, all digital assistants have a female first name and voice, including Siri, Amazon Alexa and Ciara.

[11] These patterns, unfortunately, are also observed in other sectors.

Another existing gender bias - the so called "glass ceiling", i.e. that invisible barrier that keeps women from rising beyond a certain level - becomes evident when one considers senior roles in science and technology, both in software companies and in the academic world. One reason for low numbers of female professors is that for women it is more difficult to become a member of the scientific community, which is essential to advance in an academic career (Rosser, 2004). Female post-graduate students get less support from senior colleagues than their male counterparts (Husu, 2001). In addition, women are generally less risk-averse and rate long-term job stability higher than men, and this contributes to women pursuing permanent posts as lecturers in contrast to men becoming professors in academia, in the ICT field (Quesenberry and Trauth, 2012)[12].

Additional challenges in the quest for gender equality in the digital era stem from algorithms and data mining technologies. These risk discriminating women in numerous aspects of their daily life, including employment, marketing and even credit scoring (Favaretto et al., 2019). This evidence is supported by analysis (e.g. Kuosa, 2000) that found that the visions of ICT professionals seem gender neutral in everyday talk level; however, positive things are described in masculine words (e.g. in virtual reality everyone can be an 'emperor') and negative things are connected to women; for example, presenting a mother as an opposite to an ICT professional (Kuosa, 2000). Being a mother is often considered and presented as a problem or obstacle for a woman to create a professional career in the ICT field and to obtain a higher salary (Berki and Cobb-Payton, 2005; Quesenberry et al., 2006).

Education and the learning environment: first time evidence from the WorldSkills Survey

While the digital gender divide becomes especially evident when looking at a range of factors, including digital access and competencies, wages and innovative output of the adult population (see, e.g. OECD, 2018b), its roots causes need to be understood and addressed much earlier in life. Among them, the factors determining young people's educational choices and the role played by the environment they live in deserve special attention.

To shed some light on these important questions, this section relies on the 2019 WorldSkills survey "Youth Voice for the Future of Work - Global Report" (Worldskills, 2019). It relies on data for 9 APEC economies, namely, Australia; Canada; China; Indonesia; Japan; the Republic of Korea; Mexico; the Russian Federation; and the United States, for a total of 7500 respondents aged 18-24 who have completed compulsory education. On average, 59% of

[12] This has also to do with the unequal distribution of care activities and responsibilities.

respondents were women, 40% were men[13], and data have been weighted in the analysis that follows to account for economy-specific age and gender characteristics.[14]

The survey not only collects information related to respondents' main characteristics, such as age and gender, but also asks about individuals' family environment and educational resources. Importantly, it captures young people's perception of their future of work in an environment characterised by rapid technological change and provides helpful insights to further understand the digital gender divide.

Awareness of new technologies

Figure 7(a) sheds light on the gender differences in the introduction in economies of new technologies for the young population of the APEC economies. In addition, Figure 7(b) displays the same results but considering OECD countries.

Both in the APEC economies and in the OECD countries represented in the survey, women are, generally less aware of technologies such as big data, cloud technologies, Fintech and the Internet of Things[15]. No significant differences conversely emerge with respect to renewable energy technologies in APEC economies only and artificial intelligence (AI) in OECD countries. This is important, as it entails that women are generally less informed about or aware of a number of key technologies driving the next industrial revolution. These data are consistent with the evidence about women being less interested in technologies and making use of a relatively smaller set of digital tools (see OECD 2018b).

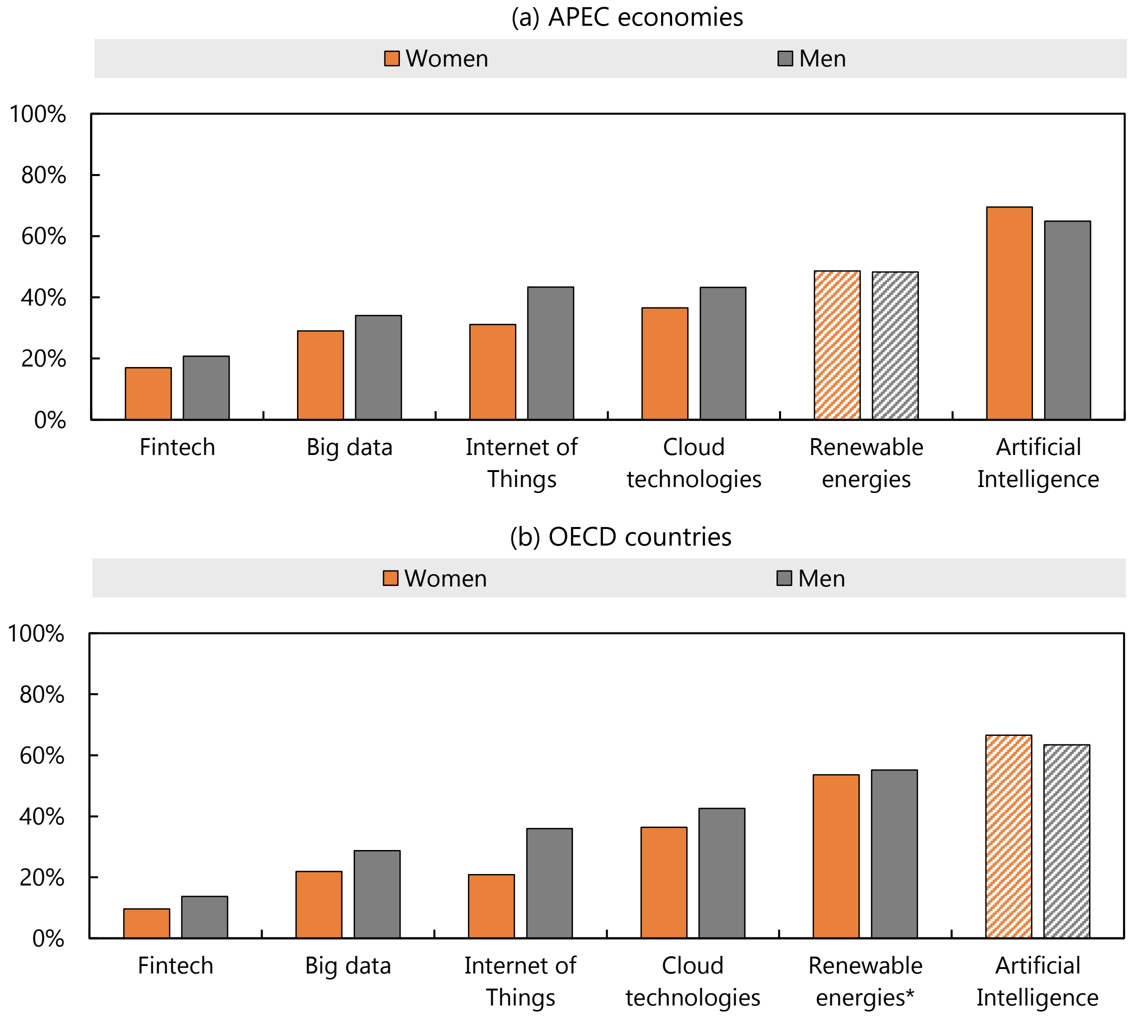
[13] 1% are third gender or did not tell.

[14] The weighting method aims to mitigate the possible biases triggered by individuals' characteristics (e.g. more active online, more willing to share opinions etc.) to the extent that these are correlated with by gender, age, or higher education achievement. Residual bias may nevertheless remain, and results need to be interpreted with care.

[15] Big data refers to: "(1) the large dimension of datasets; and (2) the need to use large scale computing power and non-standard software and methods to extract value from the data in a reasonable amount of time" (OECD, 2016c). Fintech refers to "rapid developments in financial services that are largely being driven by digital technologies" (OECD, 2018c).
An example of cloud technologies is cloud computing, which refers to "ICT services used over the Internet as a set of computing resources to access software, computing power, storage capacity and so on" (OECD, 2015b).
The "Internet of Things "refers to devices and objects whose state can be altered via the Internet, with or without the active involvement of individuals" (OECD, 2015a).

Figure 7. Women and men's awareness of selected technologies, APEC and OECD, 2019

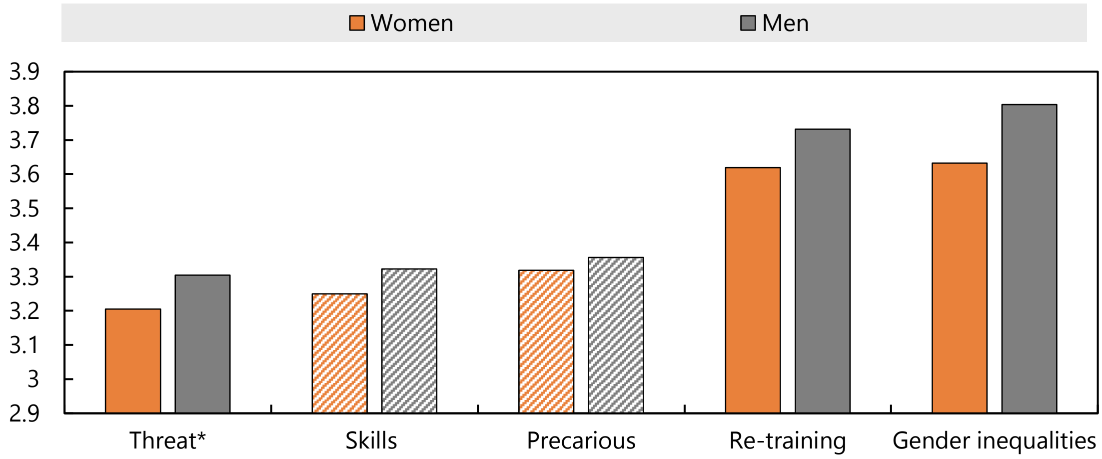
Panel (a) average of 9 APEC economies; Panel (b) average of 10 OECD countries, in percentage



Notes: The 9 APEC economies represented in the survey are: Australia; Canada; China; Indonesia; Japan; the Republic of Korea; Mexico; the Russian Federation; and the United States. The OECD countries are: Australia; Canada; France; Germany; Italy; Japan; Mexico; Turkey; United Kingdom; and United States. Bars represent the share of the population that answered "yes" to the following question: "Rapid technological developments can be expected to change lives and jobs. Which of the following technological developments have you heard of?" Hashed bars indicate that the difference for men and women is not statistically different at the 5% level; 10% levels of significance are denoted by (*). Statistics computed on weighted data.

Source: Authors' own compilation based on data from OECD/Worldskills (2019), Youth Voice for the Future of Work, https://worldskills.org/what/projects/.

Figure 8. Awareness of the possible impact of new technologies on labour market conditions, by gender, 9 APEC economies, 2019



Notes: The 9 APEC economies represented in the survey are: Australia; Canada; China; Indonesia; Japan; the Republic of Korea; Mexico; the Russian Federation; and the United States. Bars represent the average of each gender groups. Respondents answered to the following question: "Please state to what extent you agree or disagree with the following statements: (i) I worry that technological change will threaten my prospects of getting the kind of work I would like to get, (ii) I believe that technological developments will mean that I will have to retrain many times during my career, (iii) I believe that new technology will make it easier to do the sort of jobs that people of my gender have not traditionally done, (iv) I worry that there won't be much demand in the future for the knowledge and skills I have learnt and (v) I worry that I won't be able to secure permanent, full-time jobs when I am older due to future technological developments. Possible answers were encoded the following way: "Strongly agree" replaced by 5, "Somewhat agree" replaced by 4, "Neither agree nor disagree/I don't know" replaced by 3, "Somewhat disagree" replaced by 2 and "Strongly disagree" replaced by 1. Hashed bars indicate that the difference for men and women is not statistically different at the 5% level; 10% levels of significance are denoted by (*). Statistics computed on weighted data.

Source: Authors' own compilation based on data from OECD/Worldskills (2019), Youth Voice for the Future of Work, https://worldskills.org/what/projects/.

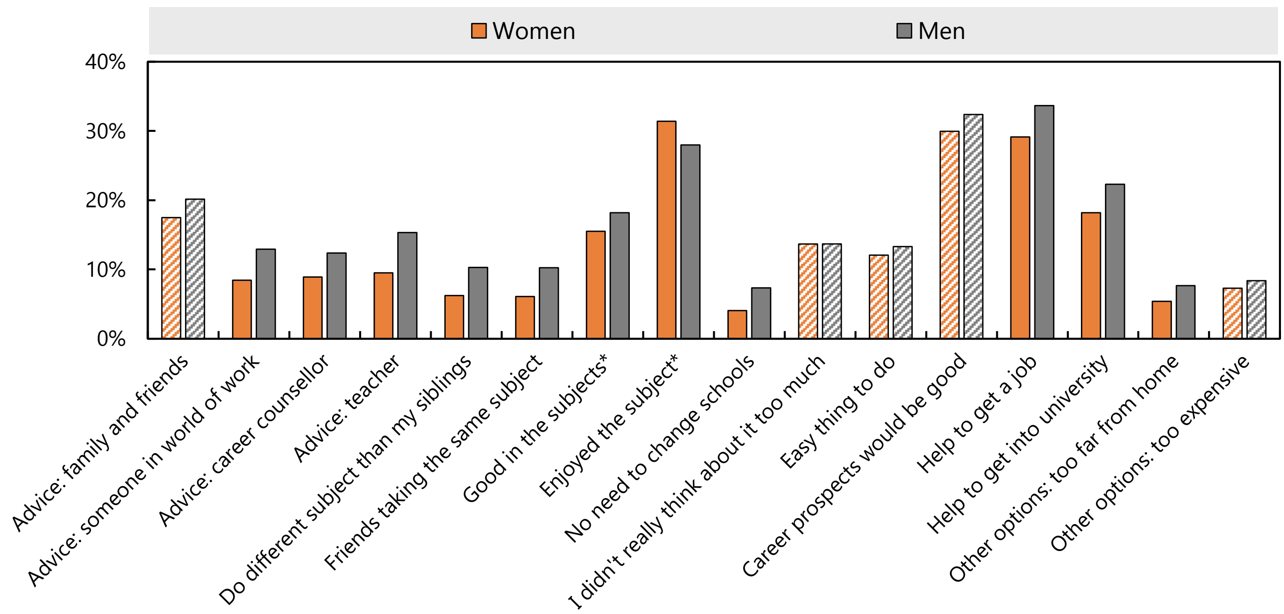
Men and women not only differ in the extent to which they are aware of new technologies, but also about the possible consequences that the generalised adoption of such technologies may have for their future as workers. In Figure 8 statistically significant differences emerge with respect to men being generally more aware about the need to retrain many times during their career. Also, and sadly so, the future looks less bright to women, as they have less positive expectations than men about new technologies helping them do the sort of jobs that women have not traditionally done.

Does the environment help?

Environmental factors influence beliefs and choices already (or especially) at a young age. Figure 9 shows that family and friends seemingly have the highest impact on young people's decisions related to the education or training programmes to follow. Also, and more so for men than for women, advice from someone from the world of work, career guidance or teachers do shape young people's decision on what to do in their future career (Figure 9 – first 4 double bars).

Figure 9. Reasons to choose a certain education or training, by gender

Average of 9 APEC economies, 2019, in percentage



Notes: The 9 APEC economies represented in the survey are Australia; Canada; China; Indonesia; Japan; the Republic of Korea; Mexico; the Russian Federation; and the United States. WorldSkills' question considered: Why did you choose your programme of education or training, once you had completed compulsory education?" Bars represent the share of each gender groups that answered "yes" to the following options: "My family and friends advised me to", "Someone from the world of work advised me to", "A careers guidance counsellor advised me to", "A teacher advised me to", "I wanted to take a different subject than my siblings", "My friends were taking the same subject", "I had done the subject(s) already and I was good at them", "I really enjoyed the subject", "I didn't need to change schools", "I didn't really think about it too much", "It was the easy thing to do", "I felt the career prospects would be good", "I thought it would help me get a job", "I thought it would help me get into university", "Other options were too far away from home" and "Other options were too expensive". The sum of percentage exceeds 100% as each respondent could select all that apply. Hashed bars indicate that the difference for men and women is not statistically different at the 5% level; 10% levels of significance are denoted by (*). Statistics computed on weighted data.

Source: Authors' own compilation based on data from OECD/Worldskills (2019), Youth Voice for the Future of Work, https://worldskills.org/what/projects/.

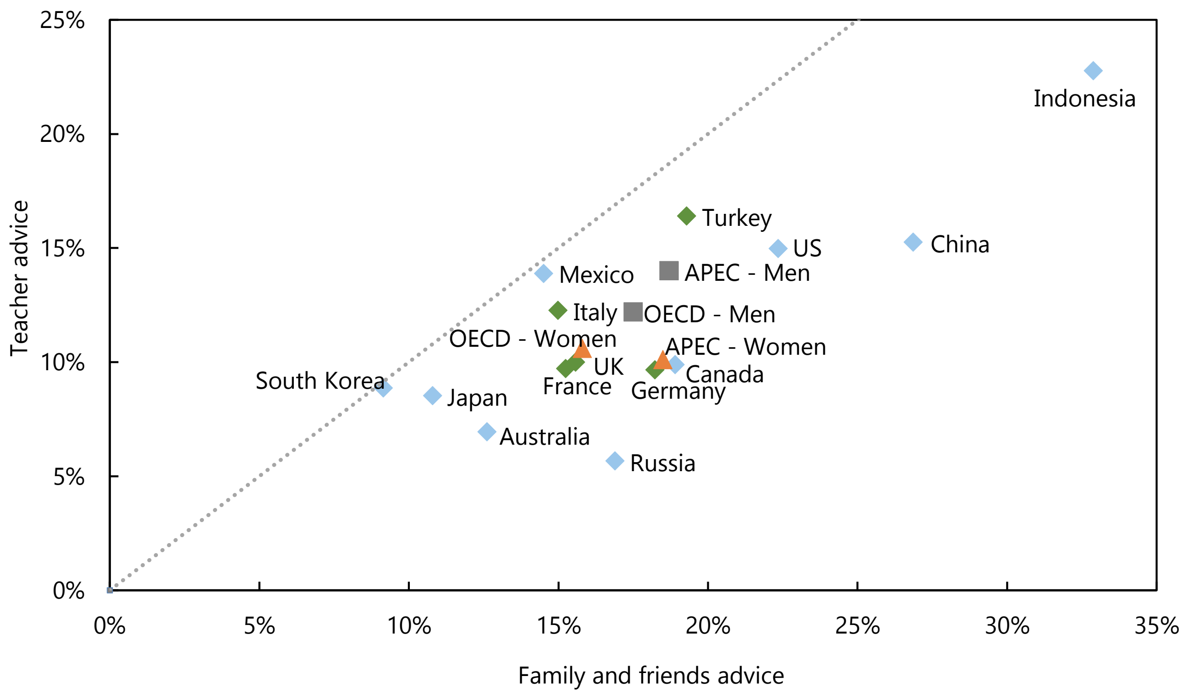
Figure 10 expands on this question and shows that in nearly all the APEC economies and OECD countries covered in the survey, family and friends' advice appears relatively more important than teachers' advice. For example, 13% of Australian respondents reported that family advice was one of the reasons why they chose their programme of education or training, while teachers' advice counted for about 7%. This is not the case, conversely, for the Republic of Korea, where teachers' advice emerged as being as influential as family and friends.

A second piece of evidence that emerges from Figure 9 is that expectations about the future of work matter, although for men more than for women. The 2 most important reasons for men when choosing education and/or training are the good career prospects that they may see and the fact that the pursued education might help them get a job. Women also consider these options as important, yet, to a lower extent than men. Women have a relatively more pronounced tendency to continue studying the subjects they enjoyed during their education, but these may not be those offering the best career prospects.

Figure 10. Share of respondents receiving advice by family or teachers when choosing a programme of education or training

APEC and OECD economies, 2019, in percentage

Why did you choose your programme of education or training, once you had completed compulsory education?



Notes: APEC economies are displayed in blue. The APEC average is displayed for both men (grey diamond) and women (orange triangles) separately. APEC economies included: Australia; Canada; China; Indonesia; Japan; the Republic of Korea; Mexico; the Russian Federation; and the United States. OECD countries' average based on 10 countries: Australia; Canada; France; Germany; Italy; Japan; Mexico; Turkey; United Kingdom; and the United States. Question considered: "Why did you choose your programme of education or training, once you had completed compulsory education?" The x-axis represents the share of respondents selecting the following statement "My family and friends advised me to" and the y-axis represents the share of respondents selecting the following option: "A teacher advised me to". Statistics computed on weighted data.

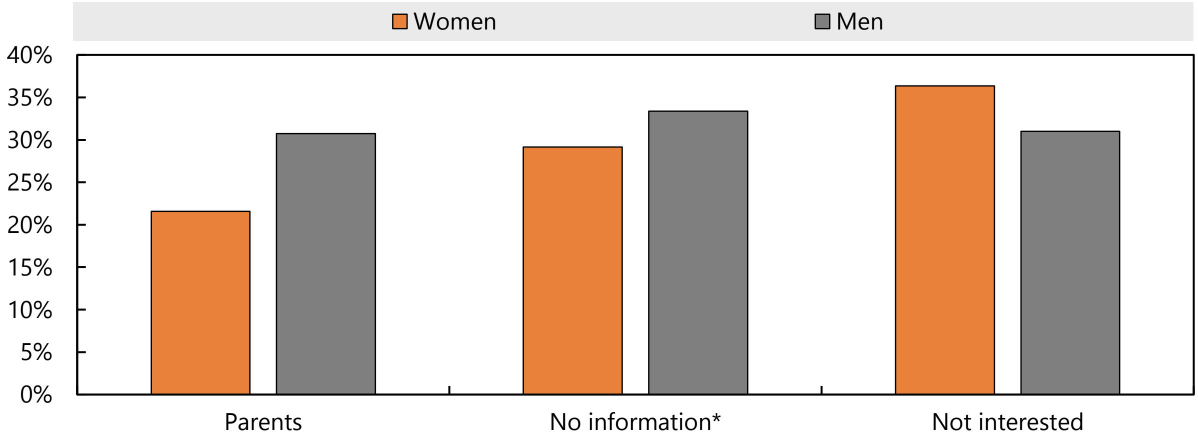
Source: Authors' own compilation based on data from OECD/Worldskills (2019), Youth Voice for the Future of Work, https://worldskills.org/what/projects/.

Figure 11 provides further elements about the importance of family for the educational choices of young adults. The share of individuals responding that their parents did not want them to do technical or vocational learning reaches 31% in the case of men and 22% for women, on average across the APEC economies for which data are available. Also, 36% of women say that that they are not interested in vocational or technical learning, which may relate to them being relatively less aware of possible job opportunities.

Figure 11. Reasons to choose higher education (i.e. university) programmes over technical or vocational learning, by gender

Average of 9 APEC economies, 2019, in percentage

"What were the reasons why you chose higher education (i.e. university) programmes over technical or vocational learning?"



Notes: The 9 APEC economies represented in the survey are: Australia; Canada; China; Indonesia; Japan; the Republic of Korea; Mexico; the Russian Federation; and the United States. Question considered: "What were the reasons why you chose higher education (i.e. university) programmes over technical or vocational learning?" Bars represent the share of each gender groups that answered "yes" to the following options: "My parents did not want me to do technical or vocational learning", "I didn't receive enough information about technical or vocational learning", "I wasn't interested in the subjects taught in technical or vocational learning". The sum of percentage may be above 100% as respondent could select all that apply. Hashed bars indicate that the difference for men and women is not statistically different at the 5% level; 10% levels of significance are denoted by (*). Statistics computed on weighted data.

Source: Authors' own compilation based on data from OECD/Worldskills (2019), Youth Voice for the Future of Work, https://worldskills.org/what/projects/.

Lacking relevant information to decide about the future?

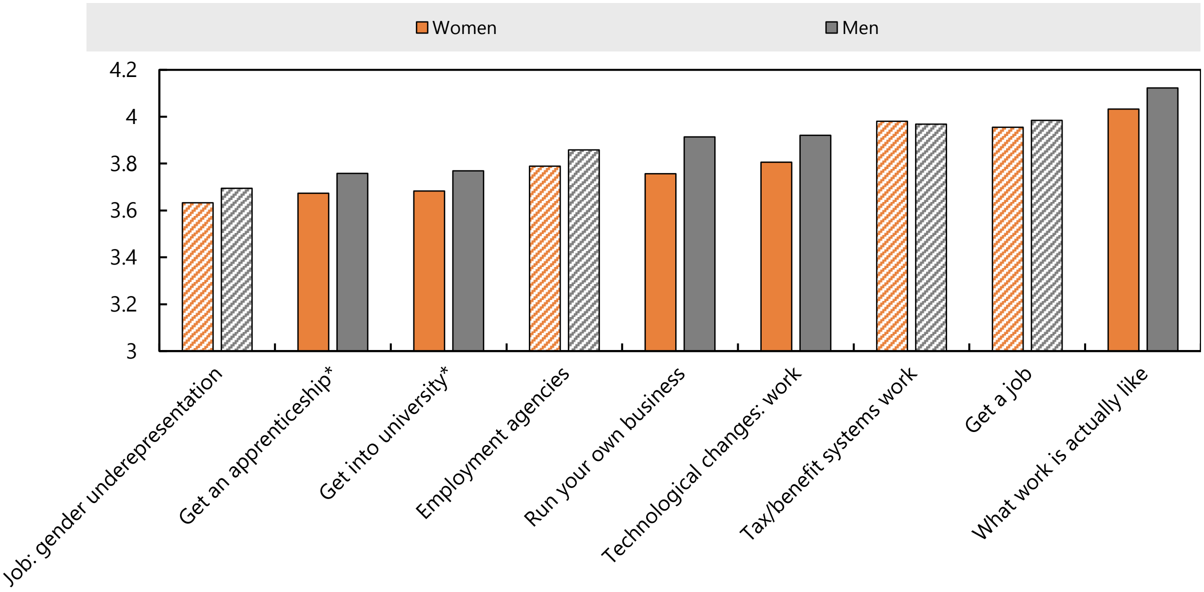
The lack of relevant information about what the future may look like can lead to disparities in the future. Figure 11 shows that in APEC economies approximately 30% of women and men aged 18-24 did not receive enough information about technical or vocational learning.

However, men systematically seem to seek and benefit more from help and advice and to worry more about their future work than women, as can be seen from Figure 9 and Figure 12. Being better informed means being able to make better choices, but women do not seemingly search for or benefit from advice and information to the extent that their male counterparts do.

Figure 12. Information sought by 18-24 years olds about the future of work

By gender, average of 9 APEC economies, 2019

"I would have welcomed more help with":



Notes: The 9 APEC economies represented in the survey are: Australia; Canada; China; Indonesia; Japan; the Republic of Korea; Mexico; the Russian Federation; and the United States. The question on which the graph relies is: “Given what you know now, to what extent do you agree or disagree with the following statements with regards to the following areas while at compulsory secondary school?” The different statement are: “ I would have welcomed more help with what work is actually like”, “I would have welcomed more help with how to get a job (e.g., applications, CVs, interview skills)”, “I would have welcomed more help with how technological changes will impact the future of work”, “I would have welcomed more help with how job centres and employment agencies work, “I would have welcomed more help with how to run your own enterprise/business”, “I would have welcomed more help with how to get an apprenticeship”, “I would have welcomed more help with how to get into university”, “I would have welcomed more help to pursue a job which people of my gender don't normally do”, “I would have welcomed more help with how the tax/benefit systems work”. Possible answers were encoded the following way: "Strongly agree" replaced by 5, “Somewhat agree” replaced by 4, "Neither agree nor disagree/I don't know" replaced by 3, "Somewhat disagree" replaced by 2 and "Strongly disagree" replaced by 1. Hashed bars indicate that the difference for men and women is not statistically different at the 5% level; 10% levels of significance are denoted by (*). Statistics computed on weighted data.

Source: Authors’ own compilation based on data from OECD/Worldskills (2019), Youth Voice for the Future of Work, https://worldskills.org/what/projects/.

Safety and security concerns

Online violence represents another major obstacle for women and girls to equally use and own digital technologies. Violence against women is prevalent throughout the world and affects women from all socioeconomic strata, cultures, and nationalities. It contributes to the origin of gender hierarchies and imbalance of power between men and women in communities and families (APEC, 2018). Online-based gender-related violence has emerged through the growth of ICT technologies and devices as the phone, Internet and email as well as social media platforms. The latter appear as an especially fertile ground for online violence (Amnesty, 2019).

Evidence shows that numerous types of abuse can occur on and through ICT and social network sites. The phenomenon of cyberviolence includes, but is not limited to, cyberstalking, cyberbullying, online harassment, misogynist speech, cyber dating abuse, and revenge porn and sexual trafficking (Amnesty, 2019; Backe et al., 2018; COE, 2018; OECD, 2018b).

Women, especially at a younger age, as well as sexual and gender minorities, are more likely to become victims of gender-based violence, in all economies. Compared to their male peers, girls are more often the object of personal attacks and cyber bulling on social networks (OECD, 2018b). Cyber bullying unlike traditional bullying, where a victim can find refuge at home, affects its victims anytime, anywhere – to the extent that a victim may feel incapable of escaping it (OECD, 2017b). While boys are more likely to be bullies in traditional forms of bullying, girls are more likely to be involved in cyberbullying as victims and as perpetrators. Girls online face more threats of sexual violence, more comments about their appearance and behaviour, and are more often told not to speak out or to have an opinion (Amnesty, 2019).

PISA studies (OECD, 2017b) showed that becoming a victim of cyberbullying and online harassment is often related to students' ethnicity, sexual orientation, physical appearance, obvious health problems and disabilities. Such increasing incidence of cyberbullying can lead to behavioural and psychosocial problems. Victims and bullies are more likely to report feeling angry, anxious, sad or depressed. They often skip school, are harassed in other ways, and are unable to focus on school tasks. In extreme cases, victims may contemplate and even attempt suicide.

Evidence shows that female Internet users are also frequently subject to harassment and hate speech. In fact, women experience an unprecedented wave of threats, violence and abuse on social media platforms, often with little accountability. The aim of violence and abuse creates a hostile online environment for women with the goal of shaming, intimidating, degrading, belittling or silencing women (Amnesty, 2019). Close to three quarters of women online have been exposed to some form of cyber violence (Broadband Commission, 2015).

A survey by Amnesty International (2017) about women's experiences of abuse and harassment on social media platforms across eight economies including the USA and UK shows that nearly a quarter of them (23%) had experienced online abuse or harassment at least once, including 21% of women in the UK and 33% of women in the USA. In both economies, 59% of the perpetrators were complete strangers.

Often, young women, especially those aged 18 to 24, disproportionately experience severe types of cyber harassment (Pew Research Center, 2014) or cyberstalking (Van Baak and Hayes, 2018). In Europe, some 11% of women (more than 20 million) have experienced cyber harassment since the age of 15 (FRA, 2014). In the USA, 21% of women aged 18 to 29 have been sexually harassed online. In addition, roughly half (53%) of young women aged 18 to 29 received explicit images they did not ask for (Pew Research Center, 2017).

Adolescents' use of ICT is also a source of concern among parents, teachers and policy makers. Students might develop dangerous relationships with strangers on line or may become victims of cyberbullying (Smith et al., 2008). Extreme video gaming, compulsive texting and overuse of smartphones are also increasingly documented. These behaviours can have serious physical, social, psychological and cognitive consequences and impede learning. Excessive use of ICT also undermines motivation and academic achievement (Borgonovi, 2016; Johnson et al., 2007), can lead to social isolation and depression (Finn and Gorr, 1988; Kim et al., 2006; Wood et al., 2004) and can hinder the development of important cognitive and non-cognitive skills.

Non-consensual pornography is a relatively new phenomenon and seems to affect predominantly, but nonexclusively, female undergraduate students. Non-consensual pornography has grown substantially in the past few years, and involves uploading nude or semi-nude images/videos of a person online without their consent. Victims of revenge porn are predominantly female undergraduate students (Henry and Powell, 2018; Marganski and Melander, 2018). The majority of private pictures that were forwarded to others beyond the intended recipient were sent by a current or former boyfriend (Branch et al., 2017). Such intimate partner cyber aggression and victimisation does not seem to be uncommon for college students, as shown in a sample from 540 college students where nearly three quarters of respondents reported having experienced some form of it in the past year (Marganski and Melander, 2018). A study found that 50% of victims' full names and links to social media profiles accompany such naked photos, and 20% of survivors' email addresses and phone numbers were posted with their photos (Citron and Franks, 2014). Once a photo is posted online, it is challenging to completely remove it from the Internet. This makes the cyber (and real) harm long lasting (Cecil, 2014).

In emerging developing economies, safety-related concerns are among the key reasons for families' opposition to the use of the Internet or the ownership of a mobile phone for both women and girls. Online harassment remains one of the key constraints for the full uptake of ICT (Webfoundation, 2015). For example, with respect to mobile ownership, worries about being contacted by strangers and information security present a major factor limiting mobile ownership among women in Latin America. In Mexico, 40% of women (versus 24% of men) who are non-mobile owners identified being contacted by strangers as the key barrier to mobile ownership (GSMA, 2018). In Chile, 49% of women (versus 23% of men) who used a phone had not used mobile Internet because they are concerned that they or their family may be exposed to harmful content online (GSMA, 2018). Also, for women in China, harassment is among the top barriers in owning and using a mobile phone. Women and girls using the Internet can be exposed to additional risks, including cyberstalking or even sexual trafficking, and it thus become crucial to develop measures to protect and prevent gender-based violence online (OECD, 2018b).

The consequences for victims of cyberviolence can last a life-long and even end with the death of a victim. The consequences of cyber aggression can range from emotional and psychological distress to death by suicide or homicide (McNeal et al., 2018). 29% of victims of online harassment report that they were scared for their life and 20% afraid to leave their homes (Stoponlinevaw, 2019).

Globally, women and girls deserve improved protection through concrete legal actions as well as schools and academic institutions deserve better support. Often, schools and academic institutions are the primary spaces and places where cyber sexual violence against young women takes place but they are not always best equipped with the knowledge and expertise to intervene, prevent and offer support (Pashang et al., 2018). Further, victims of online harassment report that the laws do not seem strong enough for online harassment (Stoponlinevaw, 2019). In Europe, some 5% of women (9 million) had experienced stalking, and from among these 23% "had to change their email address or phone number in response to the most serious case of stalking" (FRA, 2014).

Discrimination and restrictions to physical integrity are key components of the Social Institutions and Gender Index (SIGI), a new composite measure of gender equality, based on the OECD's Gender, Institutions and Development Database. SIGI focuses on the root causes beyond inequality outcomes and measures social institutions that are mirrored by societal practices and legal norms that produce inequalities between women and men. Its innovative indicators on social institutions allow identifying problematic economies and dimensions of social institutions that deserve attention by policy makers and would need to be scrutinised in detail. These include discrimination in the family, restricted physical integrity, restricted access to productive and financial resources and restricted civil liberties[16].

[16] See https://www.genderindex.org/ for more details.

Chapter 2

SKILLS FOR THE DIGITAL ERA

This chapter analyses the effects of digitalisation on skills demands and the future of work.

It sheds light on the skills that may help women narrow gender gaps (including the gender pay gap), especially in digital intensive sectors. It further provides evidence about the bundle of skills and, hence, the complementarity between different skills, that appear to be important to succeed in the Fourth Industrial Revolution, and about gender gaps in problem solving.

First-time estimates of gender differences in occupational mobility, and the possibility for women to move to different occupations if made redundant by automation are finally proposed.

Narrowing the gender gaps and succeeding in the digital era: the role of skills and skill bundles

Digitalisation is changing jobs the way we know them, their nature and tasks, and is disrupting labour markets. As the content and nature of jobs change, so do the skills that workers need to possess to perform them. It thus becomes important to understand what type of skills are needed as the digital transformation unfolds and affects production and the organisation of firms. To answer these questions, Grundke et al. (2018) offer evidence about the way different types of skills, i.e. cognitive as well as task-based skills and personality traits, are rewarded by labour markets. The idea behind the approach of Grundke et al. (2018) is that higher salaries should reflect relative skills shortage and therefore returns to skills can inform the policy discussion about the skills that labour markets demand the most. Relying on this approach it is possible to assess whether returns to skills differ by gender between industries that are more digitally intensive, as compared to those that have undergone the digital transformation to a lesser extent. Digital-intensive industries are identified following the methodology proposed by Calvino et al. (2018), which accounts for some of the key facets of the digital transformation, and recognises that sectors differ in their development and adoption of the most advanced "digital" technologies, in the human capital needed to embed them in production and in the extent to which digital tools are used to deal with clients and suppliers. The indicators used to classify 36 ISIC revision 4 sectors over the period 2001-15 are: share of ICT tangible and intangible (i.e. software) investment; share of purchases of intermediate ICT goods and services; stock of robots per hundreds of employees; share of ICT specialists in total employment; and the share of turnover from online sales.

Observing higher returns in digital intensive industries should help identify those skills that are in high demand in jobs that are more exposed to the digital transformation, and may represent a much needed complement to the deployment of digital technologies at the workplace. To this end, it is also important to investigate the skill complementarities question. This entails verifying whether and to what extent cognitive and task-based skills and socio-emotional traits are complementary, and if these complementarities differ in digital as opposed to less digital intensive industries, for both men and women.

Are men and women rewarded differently for the very same skills?

Digital technologies have the potential to reduce gender inequalities, as they may grant women ubiquitous new possibilities for participation in economies and societies, but may at the same time contribute to increase inequalities, if access, affordability and use are curtailed. This is especially the case when individuals, and women in particular, lack the education and skills needed to navigate and thrive in the digital transformation, and when the labour market discriminates against women.

Understanding if this is the case in APEC economies requires assessing whether and to what extent gender pay gaps exist. If this is the case, it is necessary to understand whether such pay gaps can be explained by differences in the skill endowment of men and women, and whether differences are more or less marked depending on the industry in which individuals work. In particular, it is important to understand whether those companies and industries that have undergone the digital transformation to a higher extent, i.e. that are more "digital intensive" (Calvino et al., 2019), contribute to attenuate or, conversely, exacerbate the gender pay gap and digital gender divide. As the future is digital, the role and behaviour of digital intensive industries is of paramount importance to understand what lays ahead and, if needed, act in order to steer its course.

The Survey of Adult Skills undertaken in the context of the Programme for the International Assessment of Adult Competencies (PIAAC[17]) makes it possible to assess the relationship between skill endowment and workers' wages. It contains a rich set of individual-level information related to workers' skills, the tasks they perform on-the-job, their workplace, their wages, the industry in which workers operate, and so on. PIAAC data are extensive and detailed and encompass 31 economies, 9 of which are APEC economies, namely: Australia; Canada; Chile; Japan; the Republic of Korea; New Zealand; the Russian Federation; Singapore; and the United States.

The gender wage gap: can differences in the skill endowment of men and women explain it?

PIAAC data allow assessing whether a wage gap between female and male workers employed in the same occupation exists. As can be seen from

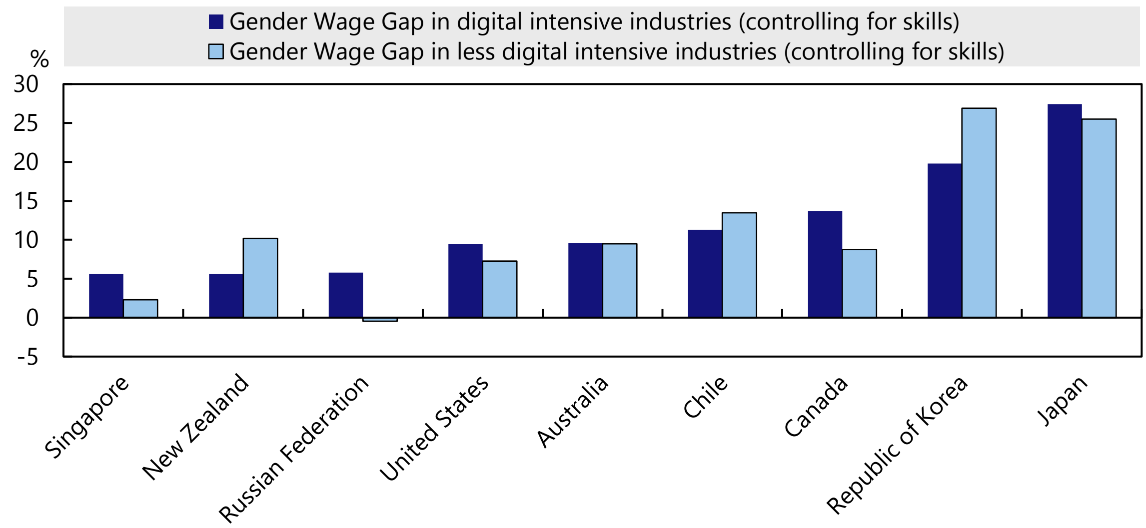
Figure 13 in those APEC economies for which PIAAC data are available, gender wage gaps do emerge, despite accounting for the skill endowment of workers. Gender wage gaps further appear generally more pronounced in digital intensive industries in Singapore; the Russian Federation; the United States; Canada; and Japan. The gender wage gap still exists but appears relatively more pronounced in less digital intensive industries in economies such as New Zealand; Chile; and the Republic of Korea. Australia is the sole economy where the gender wage gap is substantially the same in digital intensive and less digital intensive industries, although differences do emerge at the level of sectors individually considered[18].

[17] See https://www.oecd.org/skills/piaac/ for more details

[18] Industry gender pay gaps in Australia range from 5.4 per cent (Public Administration and Safety) to 26.8 per cent (Financial and Insurance Services).

Figure 13. Gender wage gap in APEC economies, digital and less digital intensive industries

Conditional difference in hourly wages for men and women, in %, 2012 or 2015



Notes: The figure shows the differences in hourly wages for men and women (in percentages) for employees in digital intensive and less digital-intensive industries. The estimates are based on OLS wage regressions, using data from the OECD Survey of Adult Skills (PIAAC), and control for a number of covariates as well as for skills.

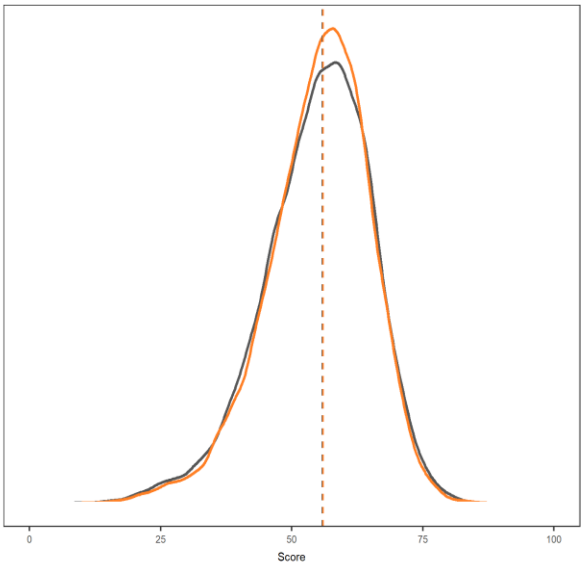
Source: Based on Squicciarini et al. in Sey and Hafkin (Eds) (2019).

It is legitimate to ask whether the observed differences in the wages paid to men and women can be explained by differences in the skill endowment of the workforce. The evidence provided in Figure 14 nevertheless suggests that the relatively small differences that emerge in the endowment of cognitive and task-based skills between men and women are not sufficient to explain the observed pay gaps. As can be seen from the density plots related to literacy, numeracy, ICT task-based skills and communication and management skills in Figure 14, the distributions of skills over the interval for men and women are very similar. Some differences nevertheless emerge. A greater proportion of men as compared to women performs above the median in terms of numeracy and of communication and management skills. Conversely, women outperform men when it comes to literacy and to ICT-related skills[19].

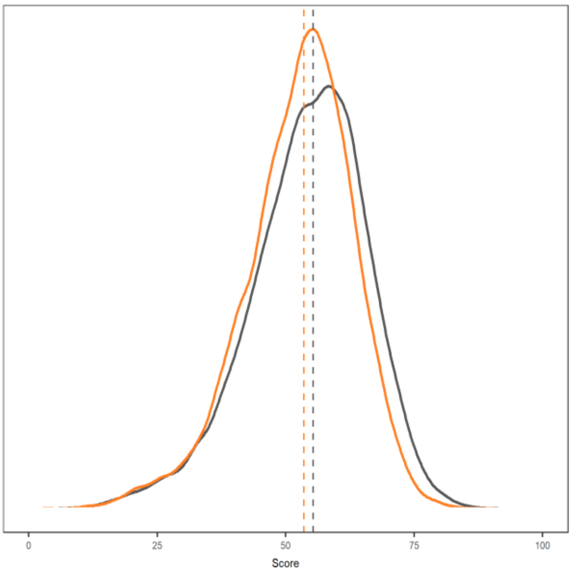
[19] Information and communication technologies (ICT)- related skills are defined as the frequency with which some simple computer tasks are performed, such as, excel use, email use, simple internet use, computer use required for the job etc. See Grundke et al. (2017) for more details.

Figure 14. Differences in cognitive and task-based skills across groups: women (orange) men (grey)

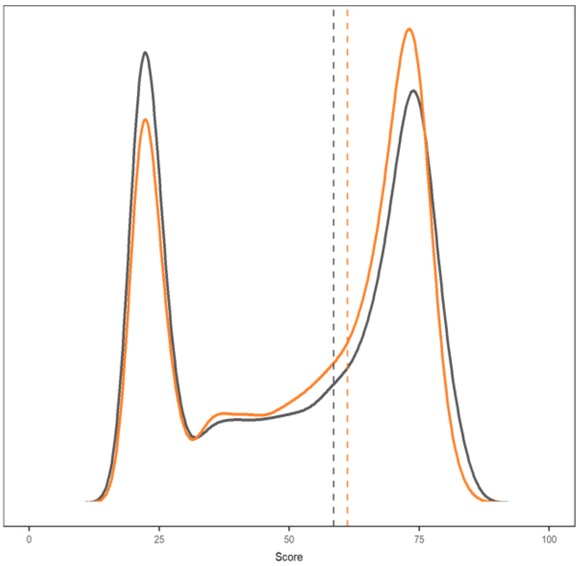
(a) Literacy



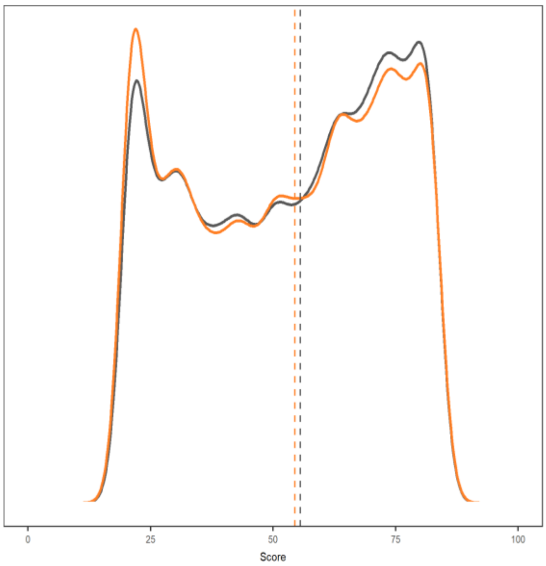
(b) Numeracy



(c) ICT-related skills



(d) Communication and management



Notes: The figure shows the densities on the y-axis. The x-axis reports the scores in PIAAC points. The orange line stands for female workers and the grey line for male workers. Medians for both gender groups are represented by the dotted lines in their respective colours. Results are based on pooled data over the 9 available APEC economies in the Survey of Adult Skills (PIAAC), namely: Australia; Canada; Chile; Japan; the Republic of Korea; New Zealand; the Russian Federation; Singapore; and the United States.

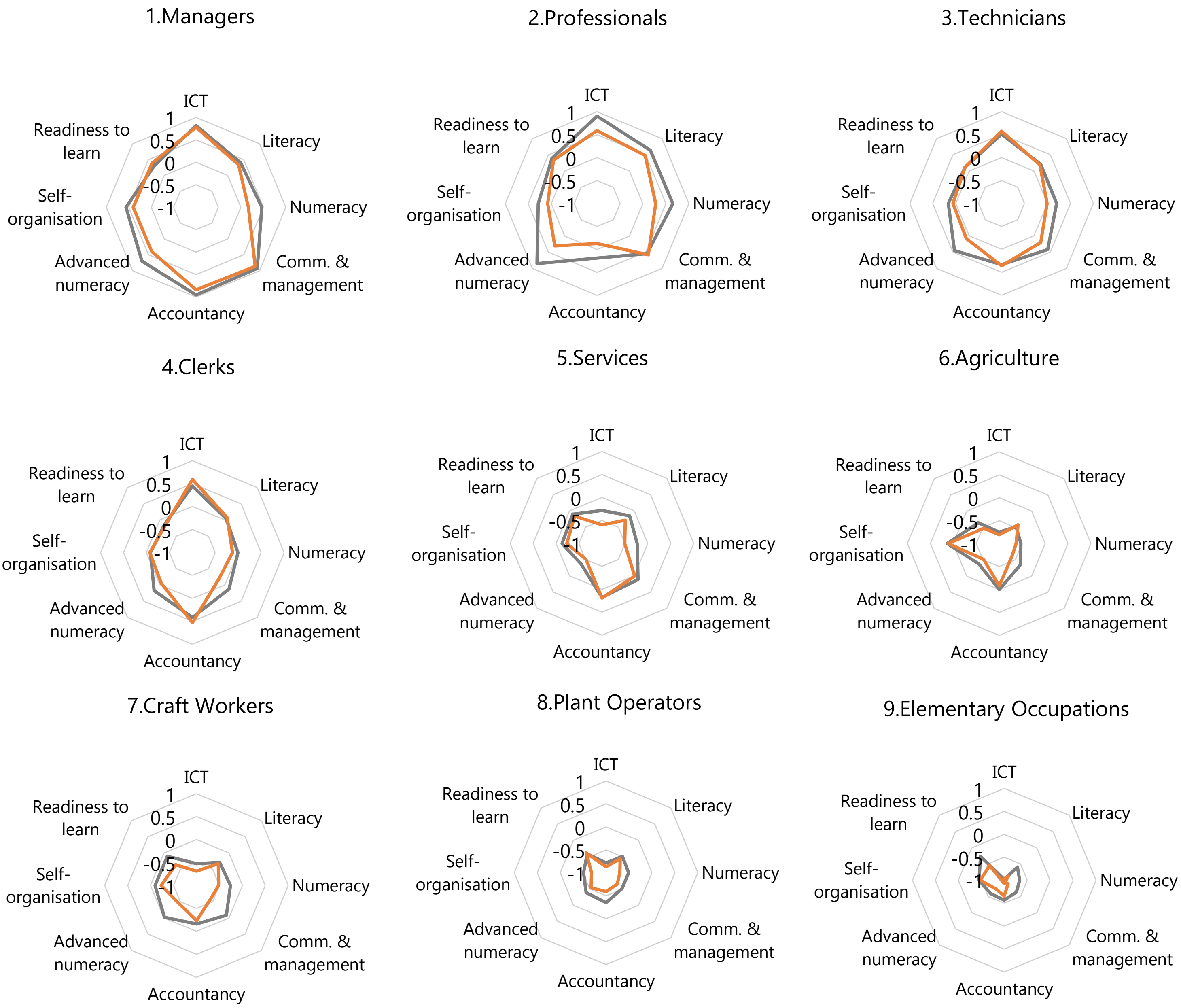
Source: Authors' own compilation based on data from the Survey of Adult Skills (PIAAC), 2012 or 2015 and on the skills taxonomy and methodological approach detailed in Grundke et al. (2017).

To shed light on the possible determinants of the observed gender pay gap it can be helpful to assess gender differences not in terms of overall levels of cognitive and tasks-based skills, (as done in Figure 14), but in terms of the skill endowment of major occupational groups. These correspond to 1-digit occupations, as classified in the 2008 International Standard Classification of Occupations (ISCO).

Figure 15 allows two stylised facts to emerge very neatly. First, that going from high skill occupations such as managers and professionals to low skill occupations such as plant operators and elementary occupations, the skills endowment of the workforce decreases importantly. Second, it can be observed that in the vast majority of cases, across all occupations and skills considered, men generally display greater skill endowments than women.

Generally, different types of skills appear to matter to different extent in different occupations, and men and women differ, on average, in the level of the skills that they possess. Despite the fact that, in recent years, women tend to gain higher levels of educational qualifications overall, males and females pursue different study programmes. As a result, men tend to display a relatively higher endowment of numeracy and of advanced numeracy. Furthermore, differences in on the job training, use of skills and responsibilities, coupled with differences in levels of self-confidence mean that men also tend to display higher levels of management and communication skills than women. These differences may contribute to partially explain the gender wage gap, if these very skills command relatively higher returns on the labour market.

Figure 15. The skill endowment of occupational groups, by gender



Notes: Each skill is represented by its average within the 1-digit occupation considered, for both gender categories. Skills represented are the following: "ICT": Information, Communication and Technologies; Literacy; Numeracy; "Comm & management": communication and management; accountancy; advanced numeracy; self-organisation; and readiness to learn. Values related to men are displayed in grey; values related to women are displayed in orange. Occupational groups are defined based on the 1-digit level ISCO 08 classification. Statistics are based on 9 APEC economies, namely: Australia; Canada; Chile; Japan; the Republic of Korea; New Zealand; the Russian Federation; Singapore; and the United States.

Source: Authors' own compilation based on the Survey of Adult Skills (PIAAC), 2012 or 2015.

Explaining differences: the gender gap in problem solving

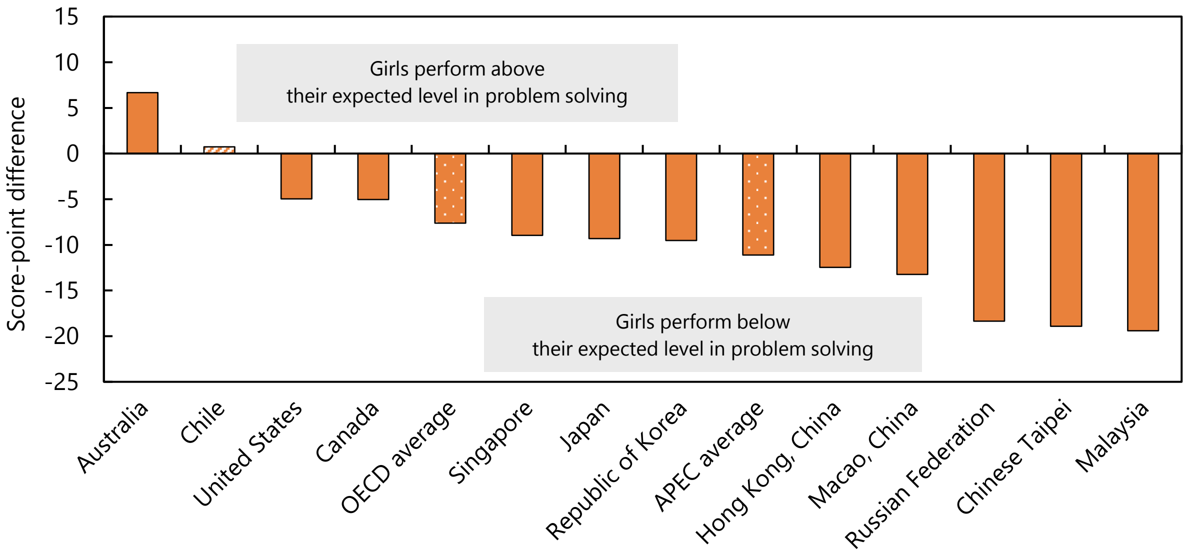
Proficiency in problem solving is a skill that appears to be essential for success in modern labour markets characterised by a high use of ICT and digital technologies (Felstead et al., 2013). It reflects individuals' capacity to deal with new problems and situations consisting of multiple elements tied by connections that are not immediately transparent and that can change because of external interventions or internal dynamics of the problem situation (Gick, 1986; Greeno, 1978; Jonassen, 1997). Problem solving reflects the capacity to engage in active and strategic exploration to be successful.

Strong stereotypes on the masculine nature of mathematics and numeracy skills exist and such stereotypes permeate how students learn, how teachers teach and how individuals see themselves and perceive others. However, no stereotypes on the feminine/masculine nature of problem solving have been defined. Analysing the competence and attitudes males and females display in problem solving is therefore instructive to understand how societies and education systems are building up or helping to narrow gender gaps in new domains that are crucial for digital and interconnected economies.

Data from PISA 2012 on 15-year-old students reveal that boys score 11 points higher than girls on average across APEC economies (7 points across OECD countries) in a digital problem solving test designed to assess students on their capacity to "engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the students' willingness to engage with such situations in order to achieve their potential as constructive and reflective citizens". In the assessment, tasks exercises simulate problematic situations drawn from real life, such as dealing with an unfamiliar ticket vending machine or an electronic device that does not work properly, in order to assess the students' general capacity for conclusion-drawing, for structuring the problem-solving process and their willingness to do so.

The variation observed among boys is also larger than the variation observed among girls. The standard deviation among boys is 100 score points, while the standard deviation among girls is only 91 score points. Similarly, the distance between the top (95th percentile) and the bottom (5th percentile) of the performance distribution is significantly larger among boys than among girls. The gender gap in problem solving was particularly pronounced in Shanghai, China and in Japan where it stood at 25 points and 19 points respectively. The gender gap in problem solving among 15-year-olds is particularly notable because in the vast majority of economies girls significantly under-perform in problem solving compared to what would be expected given their performance in curricular domains such as reading, mathematics and science.

Figure 16. The gender gap in problem solving net of gender differences in curricular domains

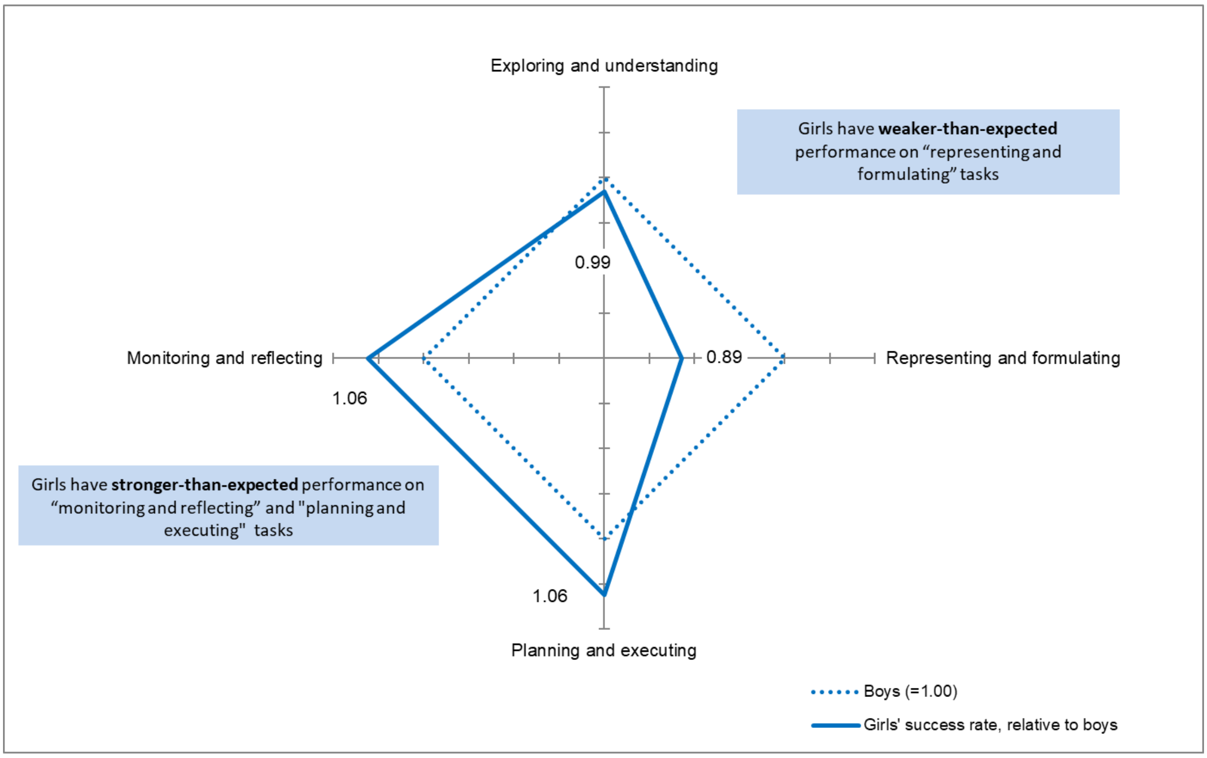


Notes: Difference in problem-solving performance between girls and boys with similar performance in mathematics, reading and science. Non-statistically significant differences are in stripped bars. Averages are displayed in doted bars. Countries and economies are ranked in descending order of the score-point difference in problem solving between girls and boys with similar performance in mathematics, reading and science.

Source: OECD, PISA 2012 Database, Table V.4.10 in OECD (2015c), Students, Computers and Learning: Making the Connection, PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264239555-en.

While the gender gap in average problem-solving differs significantly, in many of the economies that participated in PISA 2012 boys and girls also displayed a markedly different performance profile. Girls generally perform below their expected level of performance on tasks measuring "representing and formulating" processes, the cognitive processes that are key to knowledge acquisition and creation. For example, in the Republic of Korea, girls score lower than boys on the overall problem-solving scale. An analysis by families of items shows that girls' performance is much weaker than boys' on items measuring "exploring and understanding" and "representing and formulating" processes, but is close to boys' performance (and thus stronger than expected) on "planning and executing" and "monitoring and reflecting" tasks, knowledge domains that reflect knowledge utilisation. A similar pattern applies to Hong Kong, China and Macao, China as well: in both, boys outperform girls overall, and on knowledge-acquisition tasks in particular, but not on knowledge-utilisation tasks.

Figure 17. Girls' strengths and weaknesses, by problem-solving process



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

Results on 15-year-old students highlight not only that girls tend to under-achieve in problem solving tasks compared to their male counterparts but also, and crucially, that the level of their underachievement in problem solving is deeper than what could be expected given their achievement in curricular subjects and, crucially, that this underachievement is concentrated in knowledge acquisition tasks rather than knowledge utilisation tasks. Taken together these results suggest that girls may be lagging behind boys precisely in the aspects that are crucial to be play an active, leading role in digital innovations.

Problem solving was also an important competence domain in the assessment of adults that took part in the OECD Survey of Adult Skills (PIAAC). Although the assessment instruments were different, they were also geared towards measuring the capacity of men and women to solve problems in technology rich environments. Just as 15-year-old boys outperform 15-year-old girls, PIAAC evidence reveals that men perform at a higher level than women in problem solving in technology rich environments tasks. On average across APEC economies and economies that took part in PIAAC, the proportion of men who are proficient at Level 2 or 3 in this domain is 5 percentage points bigger than that of women. The largest gender difference (11 percentage points) is observed in Japan. Interestingly, in economies that are most proficient in these skills, men's performance advantage over women is larger than average.

Among young adults aged 16-24, there is virtually no difference, on average, in the proportions of men and women who are proficient at Level 2 or 3 in problem solving in technology-rich environments.

The use of computers as the delivery platform for the OECD Survey of Adult Skills not only enabled the development of new and innovative item types, such as interactive scenario-based items, but also the collection of a broader range of information, including timing data and information on how test takers engage with the computers while completing assessment tasks (He and von Davier, 2016) These data are generally referred to as log-file data. Thanks to this information it is possible to identify and characterise the problem solving strategies respondents engaged in and explore differences in the strategies adopted by men and women to consider how they approach ICT embedded problems and tasks.

In the context of large-scale assessments, items designed to test problem solving skills generally embed the problem within a particular context or situation. Therefore, the interpretation of log-file data for any individual item is highly dependent on the particular task being analysed and the context in which this item is embedded. Previous research has examined the problem solving behaviour of individuals by analysing sequence patterns of individual items (Xu et al., 2018; He and von Davier, 2016; He and von Davier, 2015; Greiff et al., 2015). However, important insights can be gained by investigating generalised patterns of respondents' behaviours across multiple tasks (i.e. multiple assessment items) embedded in different contexts and scenarios.

An important challenge for researchers willing to identify and characterise respondents' problem solving strategies is how to define variables that have a consistent meaning across items and derive standardised measures in complex data structures across multiple items. He et al., (forthcoming) use the longest common subsequence (LCS) method, a sequence-mining technique used in natural language processing and biostatistics (Sukkarieh et al., 2012) to identify the action sequences that are most similar to predefined, optimal sequences for each test item. Measurement indicators are developed in order to analyse behaviours across items and subgroups of respondents. This approach allows to extend the research capacity from mapping if individuals respond correctly or incorrectly on different test items and understanding adults' problem-solving behaviours in a single item to a general perspective on behaviour that occurs across multiple items that form an assessment.

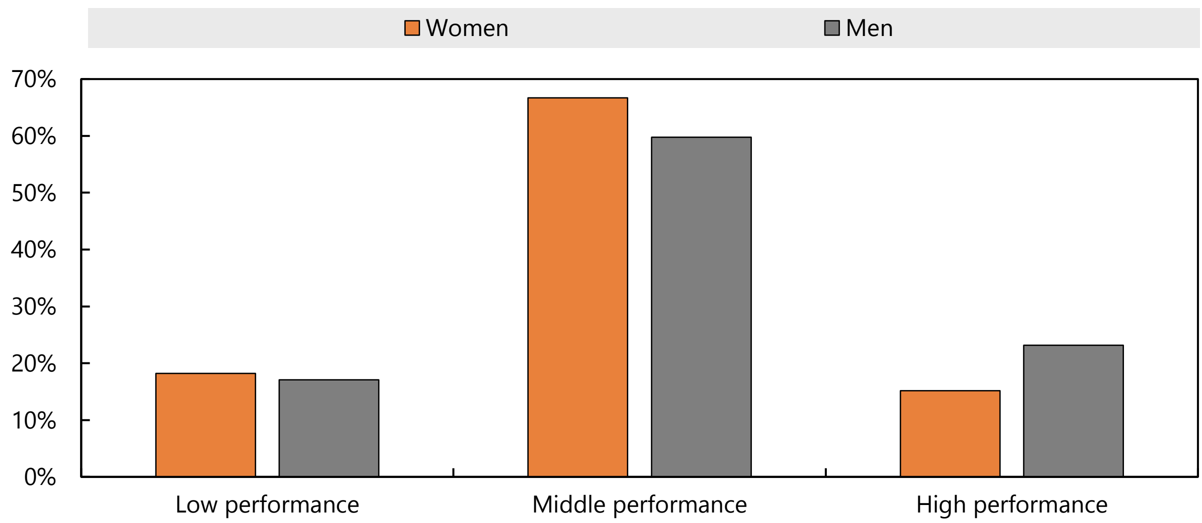
Technical details on the use of the longest common subsequence method can be found in He et al., (2019). For the purposes of this chapter it is important to consider that, for each of the problem solving item under consideration, item developers were consulted to identify the sequence (or sequences) of actions that were optimal (i.e. at each stage of the solution pathway they involved the smallest number of steps) and individual actions were compared to these optimal strategies.

Indicators were derived to consider the extent to which on average an individual engaged in problem solving behaviour that was close to optimal as well as how consistently individuals engaged in behaviour that was close to (or far from) optimal behaviour.

Individuals who participated in PIAAC were allocated to one of three groups depending on how close their behaviour was to the optimal solution strategy for each assessment task. The high similarity group indicates a high degree of match between response patterns and optimal solution patterns. The low similarity group indicates a low match between individuals' response patterns and optimal solution patterns while the medium group refers to a moderate match between the two. Results presented in Figure 18 illustrate the share of men and women in the different similarity groups for items in the PIAAC problem solving assessment. Women are over-represented in the low and moderate similarity groups, while men are more likely to be present in the high similarity group meaning that their solution pathways tend to be similar to the optimal solution pathway both because they tend to be less likely not to engage in necessary behaviour, falling short of what is required to solve a problem but also because they are less likely than women to engage in unnecessary steps. However, women showed a significantly higher degree of consistency[20], implying that they generally followed a more stable pattern of problem-solving strategies than males, no matter whether their problem-solving strategies were farther or closer away from the predefined reference sequences.

Figure 18. Gender differences in problem solving behaviours

Share of men and women in different similarity groups



Notes: Performance is defined as the adoption of problem-solving strategies that are close to optimal solution strategies.

Source: Authors' own compilation based on PIAAC 2012 Database. Problem solving in technology rich environments assessment following the methodology detailed in He, Borgonovi, and Paccagnella (2019).

[20] $T(6005) = 1.65, P = 0.003$

Returns to skills: are men and women rewarded differently for their skills?

Assessing whether gender differences exist with respect to the way cognitive as well as task-based skills and personality traits are rewarded in digital intensive industries and less digital intensive industries entails looking at returns to skills (as done in OECD, 2018b).

Skills in short supply should grant workers relatively higher returns. Hence, estimating whether returns to skills between male and female workers differ and understand, within each gender groups, what are the skills that are most rewarded should provide valuable information for policy. Identifying the skills that are most needed in the digital era and that would allow women to thrive on the labour market and reduce the gender pay gap aims to inform the design of education and training policy targeting skill shortages and addressing gaps.

As can be seen from Figure 19, in both APEC and OECD economies, ICT skills command the highest wage premiums for women, and can thus help narrow the existing wage inequalities between men and women (see also OECD, 2018b). The other skills commanding the greatest returns are numeracy skills for female workers in APEC economies and management and communication task-based skills for women in OECD countries. These skills appear not only to be highly valued in the case of female workers, but in digital intensive industries women may enjoy higher wages of approximately 3%-5% thanks to these very skills, depending on the economy considered.

It can further be observed that women's returns are generally more heterogeneous across the skills considered, whereas men's returns appear relatively more homogenous, with men that display statistically higher returns in numeracy and advanced numeracy.

In addition to showing the extent to which cognitive and task-based skills are valued in OECD countries and in APEC economies, Figure 19 shows, and very clearly so, that age penalises women but not men. Also, age is seemingly more detrimental to women in APEC economies than it is in OECD countries. Also, having kids may even be an advantage for men in both OECD and APEC economies, as it seemingly commands higher salaries. This possibly happens at the expenses of their spouses, who may have to remain at home to take care of the kids. Reducing the barriers for women who have kids to enter and remain in the labour market thus becomes a must for all economies, especially APEC ones.

A number of robustness checks (not displayed here) show the gender wage gap to be "robust", i.e. to remain very much visible and important, despite the inclusion of individuals' job and industry characteristics which may to some extent explain it, and independently of the way in which individual unobserved heterogeneity is accounted for.

Figure 19. Women and men's labour market returns to skills, 2012 or 2015

APEC economies (a) and OECD countries (b)

Notes: The estimates are based on OLS wage regressions performed separately on the two samples, using data from the OECD Survey of Adult Skills (PIAAC), and control for a number of covariates as well as for skills. Panel (a) is based on pooled data for 9 APEC economies for which data are available, namely: Australia; Canada; Chile; Japan; the Republic of Korea; New Zealand; the Russian Federation; Singapore; and the United States. Panel (b) is based on pooled data over 29 OECD countries for which data are available, namely: Australia; Austria; Belgium (Flanders); Canada; Chile; the Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Israel; Italy; Japan; the Republic of Korea; Lithuania; the Netherlands; New Zealand; Norway; Poland; Slovakia; Slovenia; Spain; Sweden; Turkey; United Kingdom (England and Northern Ireland); and the United States. The dummy "have kids" equals 1 if the number of kids is strictly superior to 0 and 0 if not. The dummy "age above 40" equals 1 if the worker is (strictly) older than 40 years old, 0 if not. Coefficients cannot be compared across samples. Shaded (i.e. paler) bars signal that the difference between women and men is not statistically significant. Striped bars denote coefficients that are not significant at the 5% level. R-square values, accounting for the overall fit of the regression model, are smaller for APEC economies than for OECD countries.

Source: Authors' own compilation based on data from the Survey of Adult Skills (PIAAC), 2012 or 2015 following the methodology detailed in Grundke et al. (2018) related to returns to skills.

Gender-specific skill returns in digital versus less digital industries

The analysis performed thus far on the one hand shows that endowing women with more ICT skills can help narrow the gender wage gap. On the other hand, though, it emerges that, generally, women tend to be less rewarded than men for the very same skills, although these general patterns may hide variations in the way firms and industries differ when it comes to rewarding skills.

Given that the future is digital, it is important to understand whether the gender pay gap risks worsening in the future. This can be to some extent inferred from looking at whether digital intensive industries reward men and women differently, and the type of skills that are rewarded in different ways.

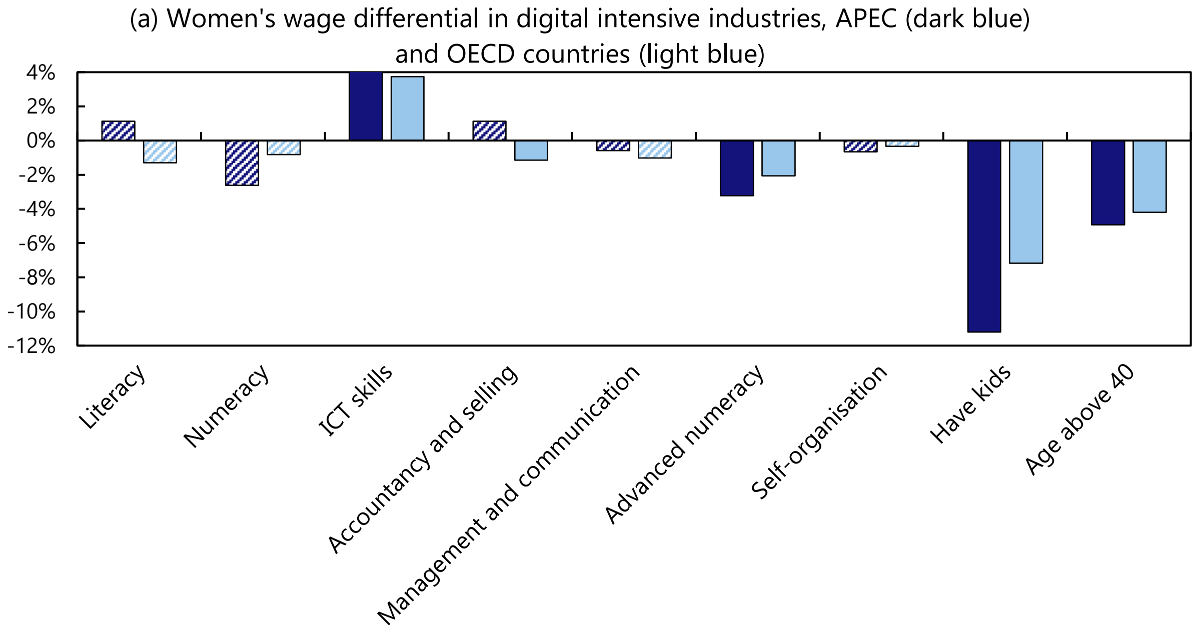
As can be seen from Figure 20, differences do emerge in the way skills are rewarded in digital intensive versus less digital intensive industries, and between men and women. In APEC economies, differences in the skill returns of men and women in less digital intensive industries emerge as being significant when it comes to literacy, ICT skills, and numeracy (both general and advanced), all skills that markets appear to be demanding to a high extent. For APEC economies, in digital intensive industries, relatively fewer skill returns display a gender divide, namely ICT skills and advanced numeracy. Patterns appear similar, albeit not identical in the case of OECD countries.

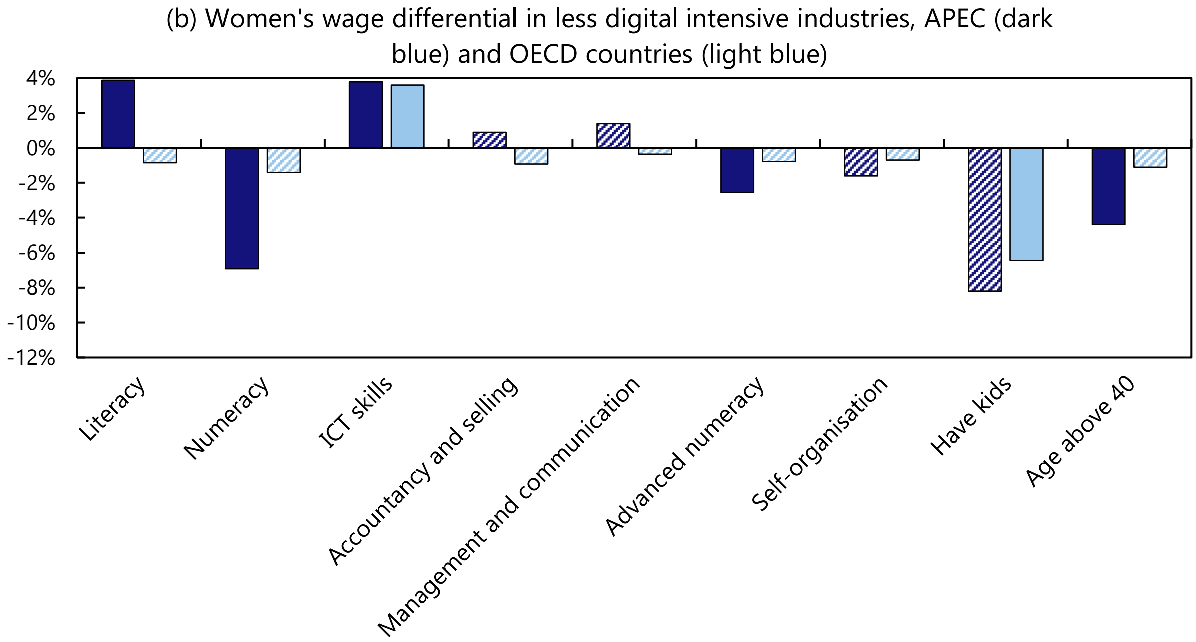
Figure 20 further highlights the important and negative effect that demographic characteristics such as having kids and being above 40 years of age may have on workers' returns to skills. In both APEC economies having kids and working in a digital intensive industry may lead women to earn 11% less, on average, than their male counterparts[21]. In addition, age leads to lower returns to skills in all industries in the APEC economies considered, whereas it does so only in digital intensive industries in the OECD countries in the sample.

[21] While the analysis cannot fully assess the causes leading to the observed gender wage gap, the factors emerging as being correlated with lower salaries for women signal possible discrimination against them based on demographic characteristics. It would be important for future analysis to try and shed more light on these dynamics.

Figure 20. Women's wage differential in APEC economies and OECD countries

(a) digital intensive industries and (b) less digital intensive industries, 2012 or 2015





Notes: Estimates based on separate OLS wage regressions for women and men in digital and less digital intensive industries, using data from the OECD Survey of Adult Skills (PIAAC), and control for a number of covariates as well as for skills. The dummy "have kids" equals 1 if the number of kids is strictly superior to 0 and 0 if not. The dummy "age above 40" equals 1 if the worker is (strictly) older than 40 years old, 0 if not. APEC economies stands for: Australia; Canada; Chile; Japan; the Republic of Korea; New Zealand; the Russian Federation; Singapore; and the United States. OECD economies stands for: Australia; Austria; Belgium (Flanders); Canada; Chile; the Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Israel; Italy; Japan; the Republic of Korea; Lithuania; the Netherlands; New Zealand; Norway; Poland; Slovakia; Slovenia; Spain; Sweden; Turkey; United Kingdom (England and Northern Ireland); and the United States. Hashed bars indicate that the returns to skills for men and women are not statistically different at the 5% level.

Source: Authors' own compilation based on data from the Survey of Adult Skills (PIAAC), 2012 or 2015, http://www.oecd.org/skills/piaac/data/, following the methodologies detailed in Grundke et al. (2018) in relation to returns to skills and Calvino et al.'s (2018) in relation to the digital intensity of sectors.

Which skills to succeed in the digital era?

The analysis proposed thus far has mainly focused on the skill endowment of the working population and on understanding which skills and individuals' characteristics matter on the labour market and command relatively higher rewards for workers, and for women in particular (see also Squicciarini et al. in Sey and Hafkin, 2019; OECD, 2018b).

In what follows the analysis sheds light on the skills needed in the Fourth Industrial Revolution, regardless of gender, as they emerge from companies' demand and are detailed in online jobs postings. This first-time analysis on the one hand aims to uncover the type of skills that are most demanded from some of the key actors of the digital transformation, i.e. the ICT specialists. On the other hand, it aims to provide important information about the penetration of the digital transformation in the entire world of work, by means of identifying the (type of) digital skills that workers in any occupation are expected to possess in order to be hired.

The analysis proposed here uses Burning Glass Technologies[22] data (hereafter BGT), which scans more than 40 000 online sources to track active job openings. The analysis relates to 5 APEC economies, namely: Australia; Canada; New Zealand; Singapore; and the United States.

Which skills for ICT specialists?

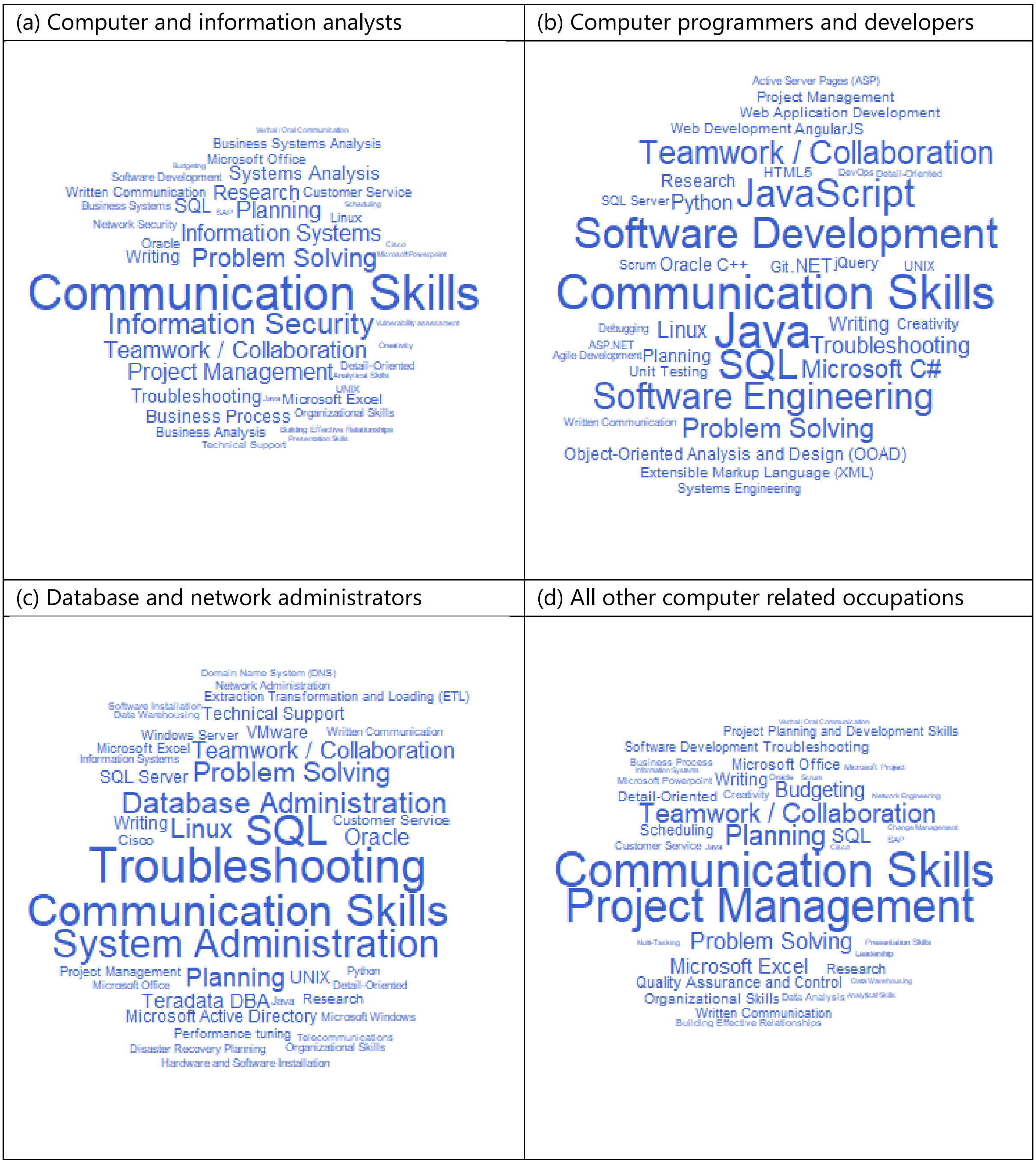
As digital technologies penetrate economies and societies, labour market demand for digital-related jobs increases.

Figure 21, focuses on the 4 occupational categories among those considered as ICT-specialists (see OECD, 2019b) that have experienced the greatest growth in demand during the period 2013-17 in the economies considered. These four occupational categories are: namely: Computer and information analysts (corresponding to the United States' Standard Occupational Classification System 2010, SOC 2010, class 15-112); Computer programmers and developers (SOC 2010 class 15-113); Database and network administrators (SOC 2010 15-114); and All other computer related occupations (SOC 2010 15-119) [23].

[22] https://www.burning-glass.com/

[23] ICT specialists are identified following the OECD-Eurostat definition (OECD, 2019b). The 5-digit occupations defined as ICT-related are identified in the 2010 Standard Occupational Classification System (SOC 2010) are: 11-114, 11-302, 15-111, 15-112, 15-113, 15-114, 15-115, 15-119, 27-401, 27-403, 27-409 and 43-901. The OECD (2019b) follows the 2008 International Standard Classification of Occupations (ISCO) and was occupational categories were converted into SOC 2010 ones in order to align with Burning Glass Technologies' data.

Figure 21. Top demanded skills, ICT-related jobs, 5 APEC economies, 2018



Notes: The word clouds display the 40 top demanded skills. The size of the words mirrors the relative percentage with which the skill is demanded in each group. Data is for 5 APEC economies: Australia; Canada; New Zealand; Singapore; and the United States. "Troubleshooting" is the process of identifying, planning and resolving a problem, error or fault within a software or computer system.

Source: Authors' own compilation based on Burning Glass Technologies, www.burning-glass.com, January 2019.

Figure 21 shows the top 40 skills that companies search for when it comes to the 4 ICT occupational categories considered.[24] As can be seen from the very size of the text – which mirrors the relative importance of the skill considered - ICT-related jobs are not only requiring workers to be endowed with a solid set of ICT-related skills, such as computer programming (e.g. JAVA, Linus and Oracle, to name a few). ICT workers are today required to have a number of soft skills including communication skills, planning skills and teamwork / collaboration skills.

Also, it can be observed that in the case of "Computer programmers and developers" a number of skills are mentioned in at least in 15% of online job adverts. This is not the case, however, for the other groups of ICT occupations considered: only few skills are more frequently demanded and many skills appear seemingly required by a relative smaller set of recruiting entities.

This lends support to what was already shown in OECD (2017a) and Grundke et al. (2018) whereby greater returns to skills where found when cognitive skills were accompanied by management and communication skills. As highlighted in the OECD (2018b) report "Bridging the digital gender divide", endowing women with these skill bundles may play an important role in reducing the gender wage gap.

Digital skills are in growing demand in all jobs

As shown above, ICT-related jobs today require both digital/ICT related skills and soft skills. But is this the case also for other occupations? On the one hand, shedding light on the pervasiveness of the digital transformation requires looking at the extent to which other, non-ICT-related jobs need workers to have ICT-related skills. On the other hand, though, it is important to see whether soft skills are important for all jobs as well and whether and to what extent demand for these types of skills has increased over time.

Figure 22 shows the skills for which demand over the period 2013-17 grew the most in the 5 APEC economies considered, with panel (a) focusing on ICT-related occupations and panel (b) on all occupations, excluding ICT ones. Interestingly enough, in the case of ICT specialists, communication skills do not appear amongst those for which demand has been growing the most, likely because demand for these skills has been sustained for some time, as can be seen from Figure 21. Conversely, some more specific and perhaps less common soft skills emerge among those for which demand is growing the most. Among them "design thinking", "agile coaching" and "salesforce platform skills".

[24] The methodology used here is similar to the one used in the OECD 2019c) "Measuring the digital transformation" report. The ICT-related occupations considered represent a subset of the ICT specialists' occupations identified in the 2010 Standard Occupational Classification System (SOC 2010) of the United States Bureau of Labor Statistics. "Computer and information analysts" corresponds to SOC 2010 class 15-112, "Programmers and developers" to SOC 2010 class 15-113, "Database and network administrators" to SOC 2010 class 15-114, and "All other computer related occupations" to SOC 2010 class 15-119.

Figure 22. Top skills for which demand grew in 2013-17

5 APEC economies, (a) ICT occupations and (b) all occupations excluding ICT-occupations[25]

(a) ICT occupations

(b) All occupations, excluding ICT

Notes: Word clouds display the 40 top growing skills, computed using the Haltiwanger formula (See Davis et al., 2006). The size of the words mirrors the relative percentage with which the skill is demanded in each group. Data are for 5 APEC economies: Australia; Canada; New Zealand; Singapore; and the United States. Only adverts containing the occupation information are kept in the analysis. Panel (a) all ICT-specialists, as defined by Eurostat-OECD (OECD, 2019b) and panel (b) all occupations but ICT ones.

Source: Authors' own compilation based on Burning Glass Technologies, www.burning-glass.com, January 2019.

Looking at all occupations but ICT ones, panel (b) of Figure 22 highlights the growing importance of ICT-related skills for all occupations. Among the most demanded there are skills related to "Data Science", "Internet of Things", "Artificial Intelligence" and "Fintech". While further analysis (not displayed here) allows differences across APEC economies to emerge, the key underlying message remains the same: digital-related skills are a must in the current world of work, and likely even more so for the future of work.

This is of paramount importance as we move to a digital future where Artificial Intelligence is going to play a key role. Some of the obstacles women have encountered in the analogue world are likely to also influence how well women will fare in the digital world, while obstacles that have long held women back are likely to see their influence grow exponentially in the digital future, if not adequately tackled. A study by West et al. (2019) for instance finds that AI, which is a field overwhelmingly made of white and male protagonists (e.g. 80% of AI professors are men), is at risk of replicating or perpetuating historical biases and power imbalances.

[25] The analysis follows the OECD-Eurostat definition of ICT specialists (OECD, 2019b). The 5-digit occupations defined as ICT-related are removed of the analysis; i.e. SOC 2010 classes 11-302, 15-111, 15-112, 15-113, 15-119, 11-114, 15-114, 15-112, 15-119, 43-901, 15-115, 27-401, 27-403, 27-409.

Evidence of this to be a real risk is that, for instance, Facebook's ad-serving algorithm was found to be discriminating by gender and race and, even in presence of a neutral advertiser, the algorithm was preferring certain groups of people over others (Hao, 2019). Also worrying is the evidence about Amazon's experimental hiring tool based on AI discriminating against women (see, e.g. Weisseman, 2018). Concerned about the future of artificial intelligence and in a view to foster the development of AI that is innovative, trustworthy and that respects human rights and democratic values, the OECD Principles on Artificial Intelligence (which were adopted on 22 May 2019 by OECD member countries) explicitly mention the need to reduce a number of inequalities, including gender-related ones[26].

The occupational mobility of female and male workers

The next industrial revolution is occurring through the confluence of new technologies, including a variety of digital technologies (e.g. 3D printing, the Internet of Things, advanced robotics), new materials (e.g. bio- or nano-based) and new processes (e.g. data-driven production, artificial intelligence, synthetic biology) (OECD, 2017c). The next industrial revolution is often (albeit perhaps imprecisely) also referred to as "Industry 4.0", when emphasis is put on the current trend of automation and data exchange, especially in manufacturing.

While the name that one may want to give to the ongoing transformation may be the object of disputes, nobody challenges the fact that the digital transformation is contributing to radically change the nature and content of jobs. Most workers are likely to see changes in the tasks they are required to perform on the job, in the very nature of their job, and perhaps may be forced to even change occupation, for example if their services are no longer required as production gets automated. Redundancies are more likely to occur when jobs feature a high proportion of routine tasks, the so called "routine jobs" (see, e.g. Autor, Lévy and Murnane, 2003; Marcolin, Miroudot and Squicciarini, 2019). Workers in those jobs will need to find an alternative occupation, likely a completely different job. The reason is that if some tasks can be automated in a certain firm of industry, chances are high that they can be automated also elsewhere.

Shielding workers from the risk of being made redundant again because of automation requires identifying alternative occupations, i.e. occupation that are not the same they currently perform and are not at risk of being automated in the short and medium term – the so called "safe haven" occupations (Andrieu et al., 2019). To this end, Bechichi et al. (2019) propose a novel methodology able to identify and measure the cognitive and task-based skill distances that exist across occupation. It further identifies the occupational transitions that can occur upon small (of up to 6 months), moderate (up to 1 year) or important (up to 3 years)

[26] Beyond OECD members, other countries including Argentina, Brazil, Colombia, Costa Rica, Peru and Romania have already adhered to the AI Principles. Also, on 9 June 2019, the G20 adopted human-centred AI Principles that draw from the OECD AI Principles.

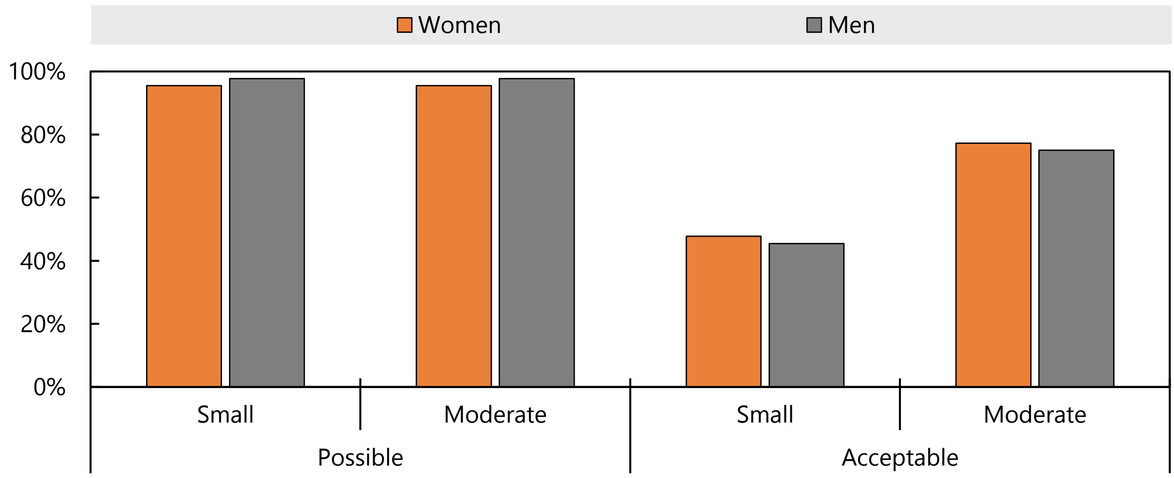
(re)training spells. Bechichi et al. (2019) further distinguish between "possible" transitions, i.e. transitions implying reasonable upskilling needs and similar knowledge areas, and "acceptable" occupations. The latter represent a subset of possible transitions and are characterised by the possibility for individuals to make maximal use of the skills they already have and to maintain income levels that are similar to the ones they had in the occupation of origin.

Which occupational transitions for men and women?

As women and men differ in the skills they are endowed with and in their occupational profiles, it is important to answer the following question. How mobile are women and men? I.e. what are the chances that, if made redundant because of automation, men and women can move to a different occupation?

Figure 23 shows the extent to which men and women at risk of being made redundant because of automation, can find at least one possible alternative occupation. The right-hand side panel of the figure further displays the share of occupations for which it is possible to identify at least one alternative acceptable occupation of destination, when short training spells of up to 6 months and moderate training spells of up to 1 year are considered. As can be seen, while in the case of men it may be slightly easier to identify possible occupational transitions, women are more likely to be able to find acceptable occupational transitions, when either training scenarios are considered.

Figure 23. Share of occupations with at least one possible vs acceptable transition, by gender group and training scenario, ROA sample



Notes: The figure shows the share of occupations of origin which display at least one successful (i.e. possible and/or acceptable) transition after a given training spell, over the total number of occupations of origin. The "small" training scenario entails training of at most 6 months, whereas the "moderate" scenario refers to training of up to 1 year. Results are based on pooled data over all economies available in PIAAC.

Source: Authors' own compilation based on data from the Survey of Adult Skills (PIAAC), 2012 or 2015, http://www.oecd.org/skills/piaac/data/ based on the methodology detailed in Bechichi et al. (2019).

For instance, after a small training spell, female workers in 42 out of the 44 3-digit ISCO2008 occupations of origin considered at high Risk of Automation (ROA, i.e. 95% of them) find at least one possible occupation of destination. This number reaches 98% for their male counterparts. The number falls to 48% of occupations of origin for women and 45% for men when acceptable transitions are considered.

Overall, the number of occupations without any possible or acceptable transitions is similar for men and women. The smaller shares of acceptable transitions relative to possible ones, stems from the fact that when transitions are required to entail limited cognitive skills excesses and wage reductions, if any, many possible transitions are not acceptable anymore.

The slightly higher proportion of acceptable transitions for women is, so to speak, the bright side of a medal, whose negative side is represented by the relatively lower wages generally earned by women (as compared to men). This makes acceptable a relatively broader range of occupations of destination in the case of women, as there are more opportunities to change jobs without (excessively) reducing income levels. Also, the relatively small tasks-based skills differences that are observed in the case of women simply reflect the fact that women are less likely to perform e.g. management and communication tasks, and therefore have not been able to acquire them.

Do men and women differ in (re)training needs?

Female and male workers differ in the type and intensity of tasks performed in the occupations of origin and in those of possible destinations, differences that translate in different (re)training needs. Figure 24 illustrates the average task-based skill training required by workers who have to train for up to 1 year to acquire the cognitive skills needed in the occupation of destination[27]. That is, these workers will need to train for a duration of up to one year to acquire the cognitive skills required on the new job, i.e. the occupation they want to move to, and, in addition, they will need to bridge the task-based skills differences displayed in Figure 24.

Overall, task-based skills shortages appear larger for women than for men, regardless of the training scenario considered[28]. For the full sample of occupations, greater shortages for women relative to men can be found in "soft skills" such as communication and management and self-organisation skills. These shortages are accentuated when the sample is restricted to those occupations that are at high risk of automation[29]. On the contrary, accountancy and selling sees its shortage reduce when moving from the full sample to the restricted one, for

[27] Training needs stand for the training required for a worker to move from an occupation of origin to an occupation of destination. In Figure 24 the set of occupations of origin and destination can differ from one group to the other.

[28] Contrary to literacy and numeracy skills, the task-based skills are computed using the frequency to which they are used on the job. Therefore, we cannot consider that women have lower levels in these task-based skills. However, it shows that women are using them on the job to a relatively lower extent than men.

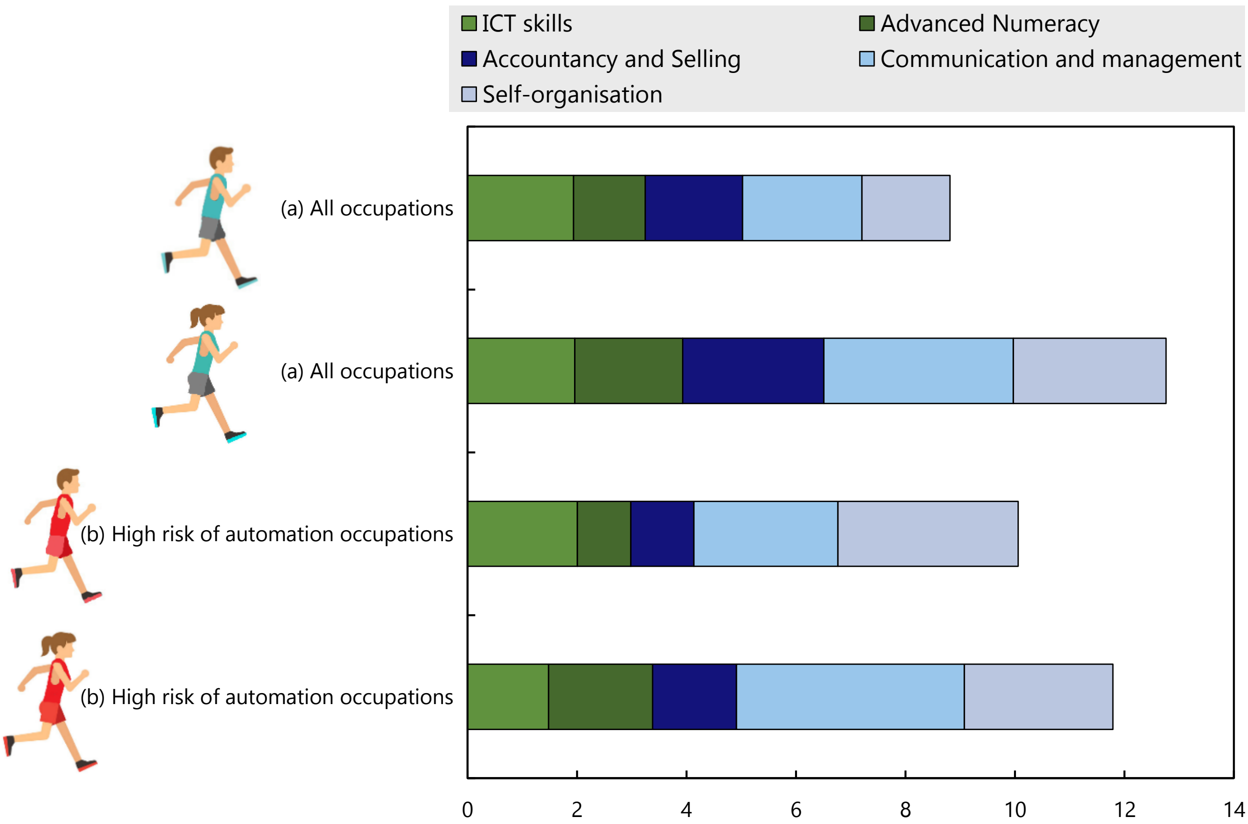
[29] The ROA sample is defined as: occupations of origin that are the ones at high risk of automation and occupations of destinations that are not at high risk of automation (Frey and Osborne, 2013).

both gender groups. This is in line with existing evidence, and suggests that adults in high-ROA occupations need to acquire especially non-cognitive skills, likely because they perform mostly routine tasks on the job. Conversely, occupations of destinations that are not at high risk of automation are more intensive in those very soft skills that make them relatively more difficult to automate. Accountancy and selling represent tasks that are more and more automatable nowadays, therefore making such skill less needed on the job.

Mobility away from occupations at high risk of automation mostly requires acquiring self-organisation and management and communication skills, no matter the gender of the worker. The same is true for female workers in the full set of occupations, but not for male workers, who seem to face similar training needs in all the non-cognitive skills considered.

Figure 24. Task-based skill training needs implied by acceptable transitions

Moderate training scenario (up to 1 year), by gender



Notes: Shortages in each task-based skill are first calculated for each occupation of origin over all acceptable occupations of destinations in the moderate training scenario (up to 1 year) and gender category, then averaged over all occupations of destinations. Bars annotated with (a) consider all occupations of origin and their transition to any acceptable destination. Section (b) instead only considers high-ROA occupations of origin finding an acceptable transition towards a medium- or low-ROA occupation of destination. The list of ROA occupations is derived from Frey and Osborne (2017).

Source: Authors own compilation based on the Survey of Adult Skills (PIAAC), 2012 or 2015 based on the occupational transitions-related methodology detailed in Bechichi et al. (2019) and on the skills taxonomy detailed in Grundke et al. (2017).

Are (re)training costs different for men and women?

Andrieu et al. (2019) proposes an experimental methodology aimed to estimate the monetary cost of the training needed to move workers across occupations. Occupations of destination are held "acceptable" if they are close, in terms of skills requirements, and entail small wage cuts and skills excesses (if any) relative to the occupation of origin. The total estimated cost encompasses the direct cost of undertaking the training, and workers' opportunity cost, in terms of foregone wages. The methodology proposed by Andrieu et al. (2019) allows estimating the cost of moving any worker, in any occupation, to a different job. This is useful, as it allows addressing the possible effects of automation on the labour force, as well as labour market changes triggered by a participation and positioning in global value chains, or any structural change or exogenous shock that may have an effect on any part of the workforce.

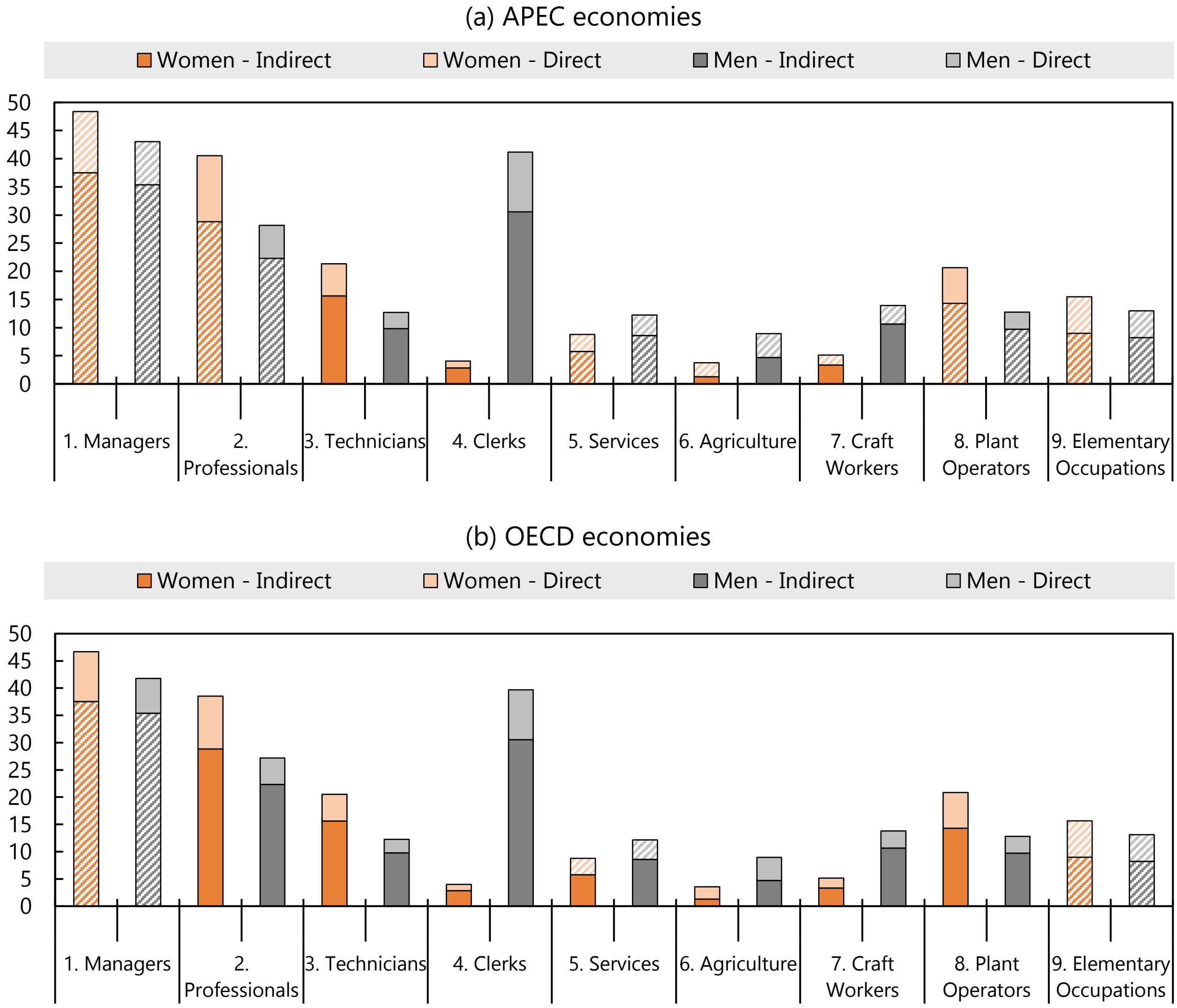
Figure 25 shows the average per-person costs of moving workers in the different 1-digit ISCO 08 occupation to acceptable occupations of destination. Figures refer to "minimum training costs", i.e. moving workers in occupations that can be reached within the narrower training effort possible, whether small (of at most 6 months), moderate (of at most 1 year) or important (of at most 3 years).

It can be observed that in APEC economies, for the 4 occupational groups (i.e. occupations defined at the 1-digit ISCO08 level) exhibiting significant differences in the direct cost[30] that needs to be incurred by men and women, female workers display higher costs in all cases except for clerks. On the other hand, the indirect cost is generally higher for male workers when differences are statistically significant. This is the result not only of the higher wages of male workers (which nevertheless represent an important component of the indirect cost), but also of the different set of acceptable transitions which emerge from the analysis for men and women.

[30] Country variations come from the cost of education, as sourced from OECD (2018a), Education at a Glance, https://www.oecd.org/education/education-at-a-glance/

Figure 25. Per-person cost of retraining by 1-digit occupations in (a) APEC economies and (b) OECD countries

Minimum cost scenario, occupations with at least one acceptable transition, in '000 USD PPP



Notes: Simple averages of costs of 3-digit occupations in each 1-digit occupation, for occupations of origin with acceptable transitions towards occupations of destination. All averages are calculated including 0-distance transitions. Costs are in thousands USD PPP. "Minimum" scenario corresponds to the occupation-specific cost of transitions towards the set of acceptable occupation(s) of destination which can be reached with the smallest training effort possible. "Direct" is the education cost of retraining workers, "Indirect" the foregone wages during the training period. APEC economies stands for: Australia; Canada; Chile; Japan; the Republic of Korea; New Zealand; the Russian Federation; Singapore; and the United States. OECD economies stands for: Australia; Austria; Belgium (Flanders); Canada; Chile; the Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Israel; Italy; Japan; the Republic of Korea; Lithuania; the Netherlands; New Zealand; Norway; Poland; Slovakia; Slovenia; Spain; Sweden; Turkey; United Kingdom (England and Northern Ireland); and the United States. Data are pooled across countries. Striped bars indicate that the cost for men and women is not statistically different at the 5% level.

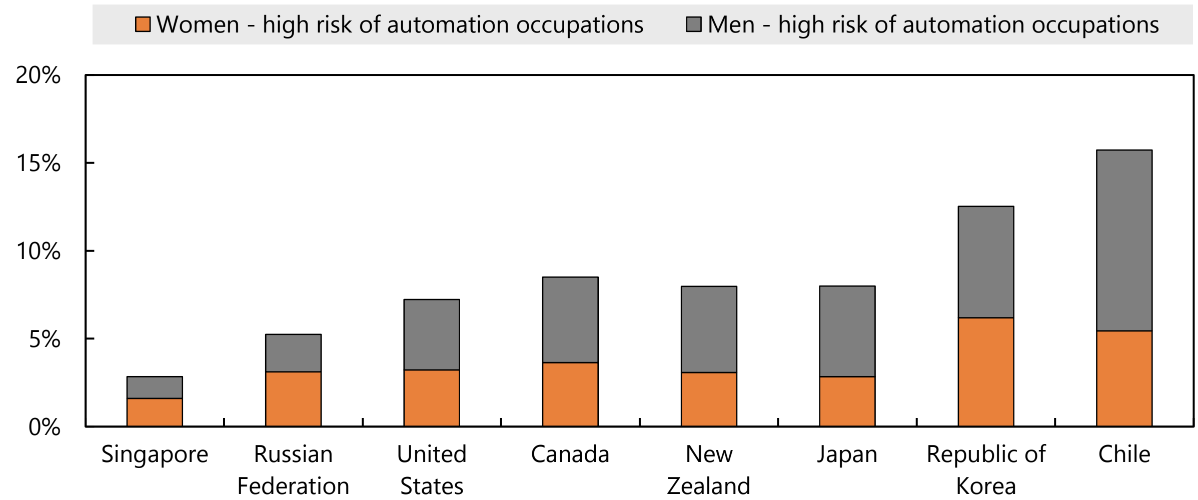
Source: Authors' own compilation based on data from Survey of Adult Skills (PIAAC) and Education at a Glance (OECD, 2018a), following the methodology about occupational transitions detailed in Bechichi et al. (2019) and the cost methodology detailed in Andrieu et al. (2019).

Economy-level estimates of the (re)training cost of moving workers at high risk of automation to "safe haven" occupations

It is interesting not only to compare the average per-worker cost of occupational transitions, but also to estimate the overall costs of moving workers at high risk of automation to safe haven occupations. Such cost is shown in Figure 26 below, as a share of one year's GDP of the economy considered. Estimates take into account the employment distribution at the economy, occupational and gender levels.

Figure 26. Maximum total cost of moving workers at high risk of automation, by gender

As a % of one-year GDP, APEC economies, 2012 or 2015



Notes: The graph shows the aggregate cost of switching workers at high risk of automation to the nearest scenario displaying an acceptable occupation(s) of destination that is not at high risk of automation. The cost only includes workers currently at high risk of automation according to Frey and Osborne that includes all workers currently employed in occupations at high risk of automation. Costs is in USD PPP and are divided by the economy's 2014 GDP. The sample excludes Australia, for which employment figures at 3-digit ISCO2008 and gender category were not available.

Source: OECD calculations based on Survey of Adult Skill (PIAAC), Structural Analysis (STAN), and Education at a Glance (OECD, 2018a) data, following the cost methodology detailed in Andrieu et al. (2019).

Looking at the subsample of workers at high risk of automation, the aggregate cost per economy (as a % of GDP) appears relatively lower for women than for men. This to some extent is explained by the relatively lower share of women in high ROA occupations that exist in APEC economies, as compared to men. In the overall sample, occupations at high risk of automation represent 38% of the occupations.

Chapter 3

THRIVING IN THE DIGITAL ERA: THE IMPORTANCE OF EDUCATION AND CURRICULUM DESIGN

This chapter provides evidence about the importance of early interventions to bridge the digital gender divide, with a particular focus on digital literacy and digital skills. It also outlines some of the key challenges faced by girls and women, with a view to identifying skills and competence needs that need to be taken into account when (re)designing education and training curricula.

The aim is to inform APEC economies' discussion on the possible strategies that could be promoted and developed in education.

The digital literacy gender divide and the importance of formative years

The digital transformation can empower women and help narrow existing gender gaps in labour market and social outcomes. However, this change depends, among several factors, on the extent to which girls and women have the skills and competencies to make the most of new opportunities (Black and Spitz-Oener, 2010; Weinberg, 2000; Goldin, 2014). Formative years are key because education systems play a crucial role, as they shape the opportunities for digital skill development. Also, early interventions aimed at remedying the onset of gender gaps in competences and attitudes that are key for success in ICT rich environments or in the factors that shape competences and attitudes are generally the most cost-effective and with long lasting impact.

UNESCO, building on a wealth of literacy frameworks used at the economy, regional and international level, developed a comprehensive definition of digital literacy as "the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital devices and networked technologies for participation in economic and social life" (UNESCO, 2018). The framework highlights seven areas of competence that, together, determine the level of digital literacy individuals possess and, with it, the ability they have to thrive economically and personally in labour markets and societies characterised by intense use of ICT and digital technologies.

Improved monitoring of all the dimensions that contribute to digital literacy and factors that are associated with their development, is crucial to identify the severity of digital literacy gaps. It is also, and equally important, to ensure that governments can be held accountable for progress and for the implementation of concerted efforts to develop digital literacy among all individuals while narrowing existing gaps.

Although comparable information on all the seven dimensions that characterise digital literacy according to the UNESCO definition are not available at the international level, this chapter identifies the size of the gender gap in key dimensions that are crucial for individuals to thrive in digital and hyper connected societies and labour markets. It then examines gender gaps in some of the pre-requisites that support the development of competences that are key to proficiency in digital literacy and how the gender gap evolves from the early years until adulthood. The chapter takes a comprehensive focus and attempts to identify gender gaps in competences and attitudes as well as factors that shape competences and attitudes both in adulthood and in the formative years.

The focus on competences and attitudes is crucial because the three aspects are all equally important to guarantee that women are able to "access, manage, understand, integrate, communicate, evaluate and create" digital content or exploit digital means for economic empowerment and self-realisation.

Over the past two decades, information and communication technologies (ICT) have transformed the ways students learn, socialise and play and the goal of education systems in enabling children to be ready for 21st century societies and workplaces (OECD, 2015c). Internet tools, including online networks, social media and interactive technologies, are giving rise to new learning styles and new learning demands where young people see themselves as agents of their own learning, and where they can produce multimedia content, update and redefine their interests, and learn more about the world, others and themselves.

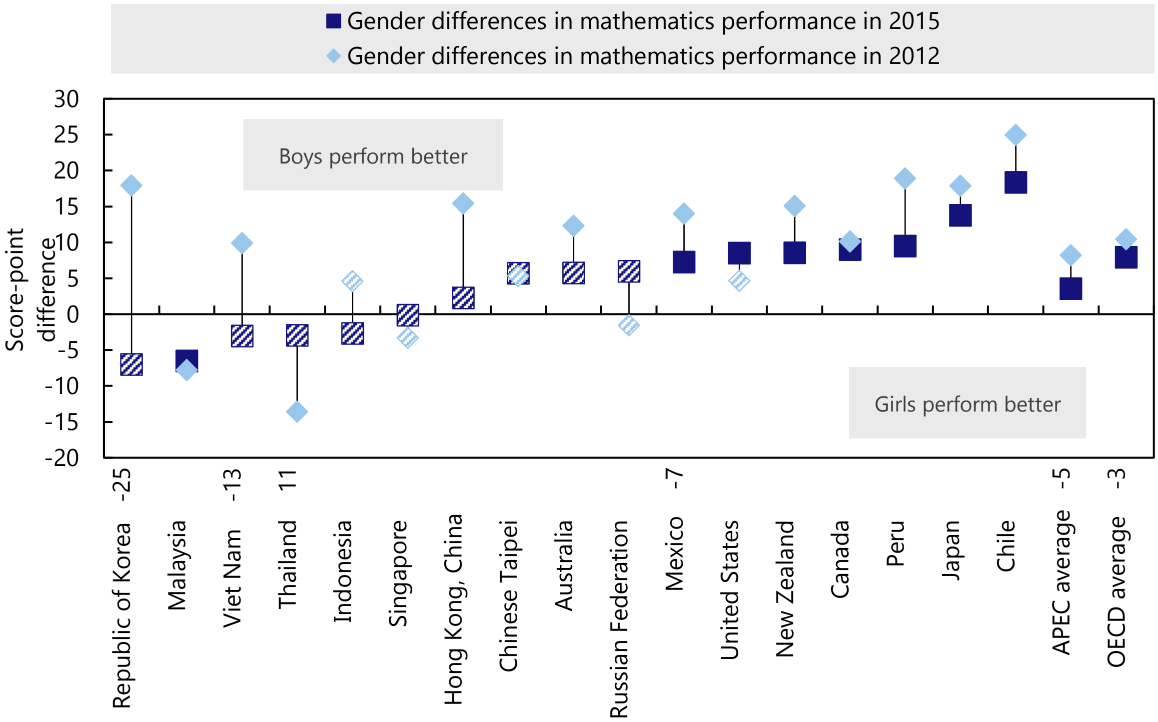
Differences in competences for digital success

Although many skills are important for individuals to thrive in digitally-intensive societies and workplaces, strong mathematics and numeracy skills are key pre-requisites. Unfortunately, data from PISA 2015 show that, although girls and women have made impressive headway in educational attainment around the world, gender gaps persist in these two key domains. Across APEC economies in 2015, boys outperformed girls in mathematics by an average of four points (OECD average eight points). The gap was wider among high achievers, with the highest-scoring 10% of boys outperforming the top 10% of girls. The gender gap among the highest-performing students (those in the 90th percentile of the performance distribution) is significant in most economies and in no PISA-participating economy do more girls than boys perform at Level 5 or above in mathematics.

In the vast majority of economies, the mathematics gender gap failed to change significantly between 2012 and 2015, data from PISA 2012 and 2015 show. Although it actually shrank by an average of 5 points across APEC economies (three points across OECD countries) over the period, it was thanks mainly to the change in one economy, the Republic of Korea, where boys' mathematics scores dropped more steeply than those of girls'. As a result, while the Republic of Korea had one of the widest pro-boy gender gaps in 2012, girls outperformed boys in 2015, although the difference was not statistically significant.

Identifying performance at the age of 15 is important because this is the age at which many boys and girls start to make decisions about their further studies and occupations or are tracked by education systems into pathways that are more academic vs. technical, focused on humanities vs. scientific subjects. However, in order to understand the full scope of the gender gap in digital potential in the labour market and societies and how this can be changed it is important to better understand the trajectory of how gender differences in skills, attitudes and behaviours evolve from age 15 until young adulthood as well as how gender differences in skills, attitudes and behaviours evolve from young childhood until age 15.

Figure 27. Gender differences in mathematics achievement, 2012 and 2015



Notes: Score-point difference in mathematics (boys minus girls). Gender differences in PISA 2012 and in PISA 2015 that are statistically significant are marked in a darker tone. Statistically significant changes between PISA 2012 and PISA 2015 are shown next to the economy name. Only economies that participated in both PISA 2012 and 2015 are shown. Economies are ranked in ascending order of gender differences in 2015.

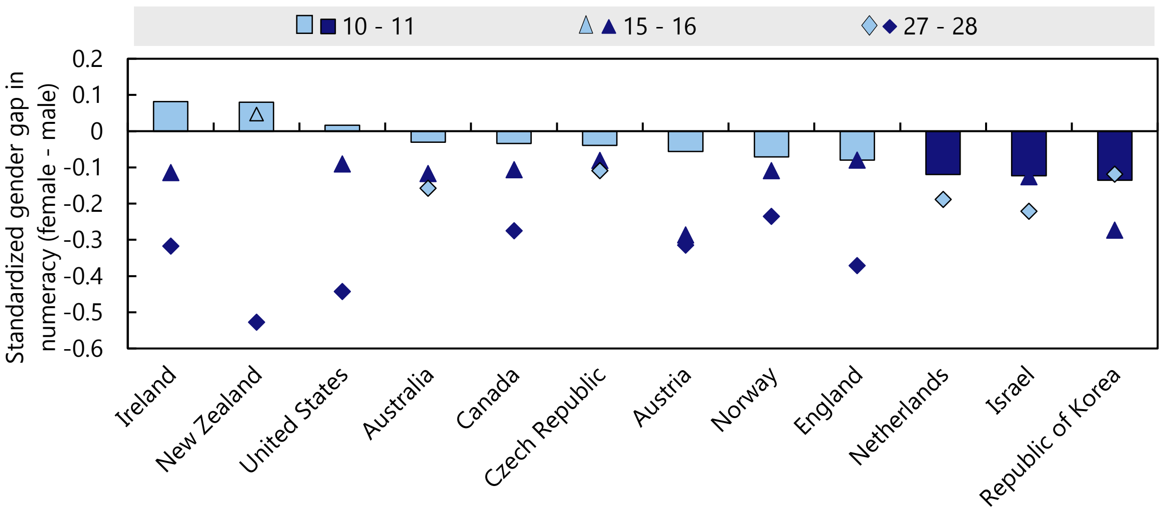
Source: Authors' own compilation based on OECD, PISA 2015 Database, Tables I.5.8a, I.5.8c and I.5.8e.

It is not possible to identify comparative longitudinal data that can be used to assess how the gender gap in mathematics/numeracy evolves as individuals age, but it is possible to use repeated cross-sectional evidence from international large scale assessments to construct synthetic cohorts and compare how the gender gap in numeracy skills evolved from young childhood into young adulthood for individuals who were born in 1984 and 1985. This group of students sat the Trends in International Mathematics and Science Study (TIMSS)[31] assessment in 1995, was broadly expected to sit the PISA assessment in 2000 and the PIAAC assessment at the age of 27-28. Unfortunately, evidence is available for a limited number of economies that took part in all three assessments in the relevant editions.

[31] See https://nces.ed.gov/timss/ for more details.

Figure 28 presents standardised gender gaps in order to allow comparisons across surveys[32]. Results suggest that in most economies gender gaps were small at age 10 and grew steadily thereafter. In particular, the gender gap in numeracy grew markedly in New Zealand; the United States; and Canada. In all three economies there was no statistically significant gap at age 10, a small gap at age 15 but a large gap at age 27.

Figure 28. The evolution of gender gaps in numeracy



Notes: Dark colours denote a statistically significant gender gap (5%).

Source: Authors' own compilation based on TIMMS 1995, PISA 2000 and PIAAC 2012.

(The right) Attitudes and behaviours are necessary complements to skills

Motivation to achieve

One of the most important ingredients of achievement, both in school and in life, is motivation to achieve (OECD, 2013). In many cases, individuals with less talent, but greater motivation to reach their goals, are more likely to succeed than those who have talent but are not capable of setting goals for themselves and to stay focused on achieving them (Duckworth et al., 2011; Eccles and Wigfield, 2002). The motivation to achieve goals not only leads individuals to pursue work they perceive to be valuable; it also prompts them to compete with others (Covington and Müller, 2001).

[32] While there is considerable commonality between mathematics in PISA and numeracy in PIAAC, there are key differences between those assessments that should be carefully considered when comparing the results of the two surveys. Among them, differences in the target populations of the surveys, in sample selection methods, in assessment instruments and in data collection environments.

Motivating students and sustaining their motivation is one of the major challenges that teachers face on a daily basis. Adolescents have new capabilities and interests that should motivate them to do well at school. As they become older, children become more able to exercise complex thought, have greater capacities for self-regulation, and hold a stronger desire for meaningful work (Damon et al., 2003). Despite these blossoming abilities and attitudes, steep declines in motivation to do schoolwork are often documented during adolescence (Lepper et al., 2005). At a period in life when school should be seen as more relevant, students rate school as less useful and important (Wigfield and Cambria, 2010). The capacity to set goals and regulate efforts to achieve these goals is not just a characteristic of the individual but also a result of the home and school environments children encounter (Eccles and Wigfield, 2002). Because people tend to form beliefs about what they can achieve in life at a young age, the development of positive motivation to achieve at school is a prerequisite for success in life, particularly in high risk, high reward environments such as digital intensive sectors.

Evidence from PISA 2015 data indicates that girls were more likely than boys to report that they want top grades at school and that they care more than boys about being able to select among the best opportunities when they graduate. But boys were more likely than girls to describe themselves as ambitious and to aspire to be the best, whatever they do. Girls thus seem to care more than boys that their efforts at school are properly recognised, but they were less likely than boys to report that they are ambitious or competitive in contexts that are not necessarily related to school. On average across APEC economies 70% of boys but only 66% of girls reported that they see themselves as an ambitious person. Furthermore, on average across APEC economies 80% of boys and 79% of girls reported that they want to be the best, whatever they do. By contrast, in OECD countries students tend to report lower overall levels of achievement motivation and the gender gap is wider: about 68% of boys but only 62% of girls reported that they want to be the best, whatever they do.

PISA data refer to 15-year-old students. As such, evidence on gender differences in skills, attitudes and behaviours pertains to differences observed among boys and girls who attend school. While in many APEC economies participation in school at age 15 is universal or nearly universal, in others many children are out of school at age 15 and drop-out rates differ by gender (UNESCO, 2019).

Safety concerns and financial considerations are important reasons in some economies for girls' greater likelihood of dropping out from secondary school. Moreover, in some economies, women leave school or do not pursue post-compulsory education because of marriage or in the wake of pregnancy. Globally, nearly 16 million girls aged 15 to 19 give birth each year; 2 million of them are under 15 (UNFPA, 2015). Among APEC economies, there is evidence that in Chile, being a mother reduces the likelihood of completing secondary education by between 24% and 37% (Kruger et al., 2009) and in Mexico, among 15- to 29-year-old women who dropped out of school in 2013, 8% listed pregnancy or having a child as a reason why they left school early, and 11% cited getting married or entering a union.

To address the issue, for instance Mexico's Ministry of Public Education has committed financial resources to support students at risk, offering scholarships with a gender component to help adolescent mothers stay in school. From 2013 to 2015, it offered more than 700,000 scholarships aimed at keeping girls in school (OECD, 2017d).

Figure 29. Gender differences in achievement motivation

Notes: Percentage of students who reported that they "agree". All differences are statistically significant at the 5% level.

Source: OECD (2017b), PISA 2015 Results (Volume III) Students' Well-Being, https://doi.org/10.1787/9789264273856-en.

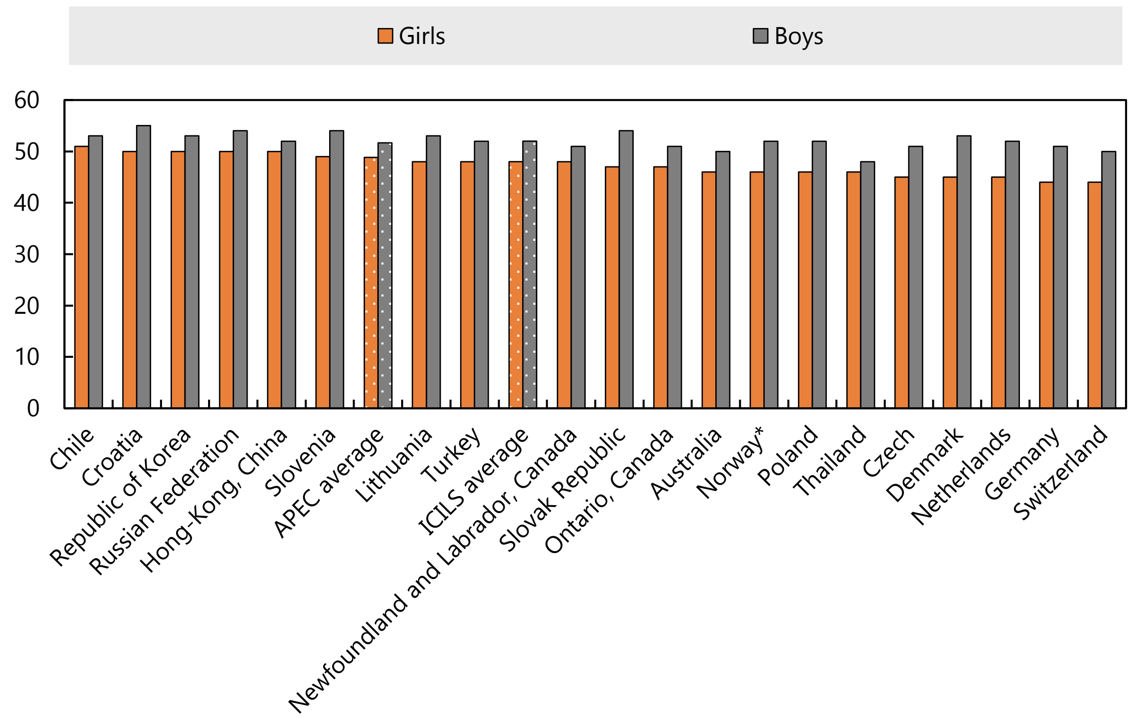
Actual performance and perceived ability differ by gender

Although the previous section portrays gender gaps in some aspects that are important for success in digitally rich workplaces and societies, differences tend to be generally small and cannot explain neither the under-representation of women in the digital and ICT sector, nor their under-representation in STEM fields more generally. This section discusses the potential role of attitudes and behaviours. The stereotype of mathematics, the physical sciences and technology as fields in which males exceed and where females lack talent is pervasive and may influence girls' confidence in their skills from a young age. By shaping the confidence girls and boys have in their own abilities, stereotypes may reduce the willingness of girls to engage in fields that are perceived to be masculine and reduce the incentives they have to do so if, for example, they reduce the likelihood that they will be considered for jobs in stereotypically masculine sectors.

Gender stereotypes influence the perceptions girls and boys have in their abilities to use technology. Evidence from the 2013 International Computer and Information Literacy Study (ICILS) which was conducted among 8th graders in 21 economies indicates that the gender gap in actual digital competence is either non-existent or reversed in favour of girls. However, girls had lower levels of self-efficacy even when they outperformed or performed similarly to boys on measures of digital skills. When responding to the ICILS student questionnaire, students indicated how well they thought they could do each of the following 13 computer-based tasks (in order of increasing difficulty) which were used to consider self-efficacy: "search for and find information you need on the Internet"; "search for and find a file on your computer"; "create or edit documents (e.g., assignments for school)"; "upload text, images, or video to an online profile"; "edit digital photographs or other graphic images"; "create a multimedia presentation (with sound, pictures, or video)"; "change the settings on your computer to improve the way it operates or to fix problems"; "use a spreadsheet to do calculations, store data, or plot a graph"; "use software to find and get rid of viruses"; "build or edit a webpage"; "set up a computer network"; "create a database"; and "create a computer program or macro". The response categories were "I know how to do this," "I could work out how to do this," and "I do not think I could do this."

The discrepancy between the gender gap in actual performance and the gender gap in self-perceptions can be seen across economies and is particularly notable for more complex skills, such as locating specific information online or creating a multimedia presentation. On the ICILS assessment, girls' self-efficacy scores – that is, their perceived as opposed to their actual abilities – for advanced ICT tasks were significantly lower than boys' in all economies.

Figure 30. Gender differences in digital self-efficacy



Notes: * 9th graders. Index standardised to have a mean of 50 and a standard deviation of 10.

Source: Authors' own compilation based on the International Computer and Information Literacy Study ICILS (2013)[33] study (see Fraillon et al., 2013).

The lower level of self-efficacy expressed by girls in digital skills mirrors similar evidence on the lower level of self-efficacy girls express in science and mathematics. Evidence from PISA 2012 and PISA 2015 indicate that 15-year-old girls are considerably less likely to report feeling confident about solving science and mathematics problems than boys of similar levels of performance in the two subjects (OECD, 2015d; OECD, 2017b).

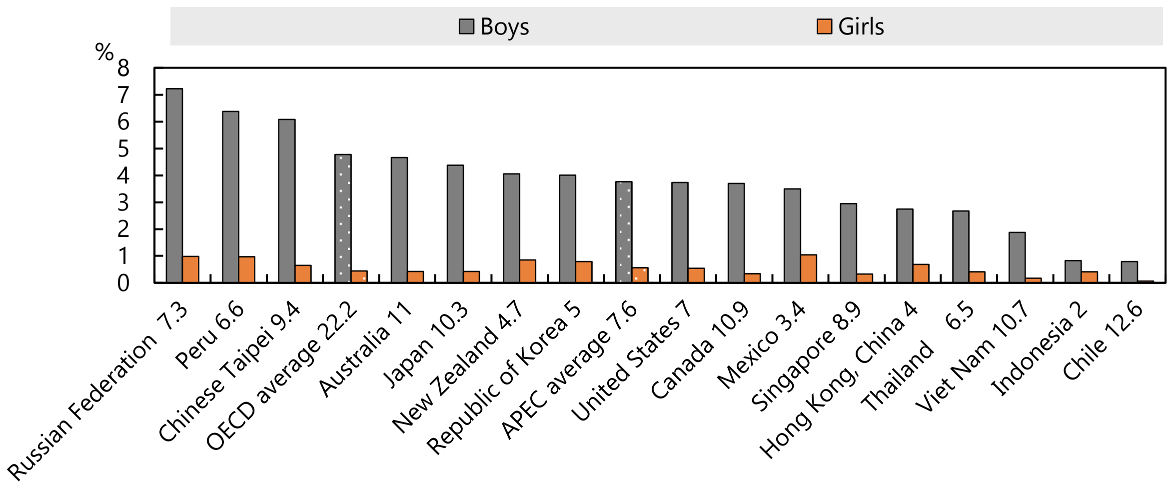
Differences in feelings of confidence inevitably spill over on the career expectations and aspirations young boys and girls develop. Students who hold ambitious expectations about their career prospects are more likely to put effort into their learning and make better use of the education opportunities available to them to achieve their goals (OECD, 2015d). Therefore, career expectations, in part, become self-fulfilling prophecies. Evidence from PISA 2015 indicates that across APEC economies, only around 0.6 per cent of 15-year-old girls aspire to work in ICT-related careers at age 30. By contrast, 3.8 per cent of boys do. The comparable figures among OECD countries are 0.4% of girls and 5% of boys. Although in all economies boys are considerably more likely to expect that they will work as ICT professional at age 30,

[33] https://www.iea.nl/icils

the relative risk of boys doing so is 7.6 on average among APEC economies participating in PISA 2015 but is as high as 22.2 on average among OECD countries.

Among APEC economies the relative risk of boys expecting to work as ICT professional relative to girls is above 10 only in Viet Nam; and Japan. In many economies the gender gap in the expectations students have of their future career prospects in STEM reflects the gendered and stereotypical nature of parental expectations: the parents of boys are considerably more likely to expect that their child will work in a STEM occupation than the parents of girls, even when comparing boys and girls of similar levels of academic achievement (OECD, 2015d).

Figure 31. Percentage of boys and girls who expect to work as ICT professionals at age 30



Notes: The relative risk for boys to expect to work as ICT professionals is next to the economy name. Economies sorted in descending order of the percentage of boys who expect a career as ICT professionals at age 30. All gender differences are statistically significant.

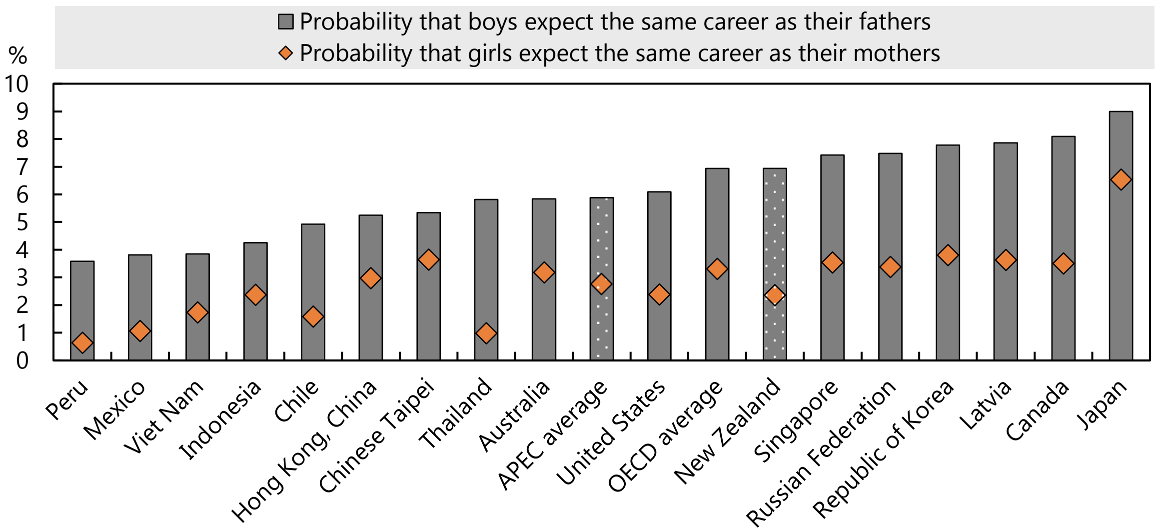
Source: OECD PISA 2015 database.

Role models matter for women to enter and thrive in technology-related sectors

The importance of role models in combating gender stereotypes and promoting greater participation of females in technology, engineering, mathematics and ICT fields of study and work has been discussed at length both in the research literature and promoted in policies facilitated by active steps organised by universities, industry organisations and by governments and international cooperation. The lack of female representation in technology-related sectors and the supposed "masculinity" of technology is often seen as a barrier that prevents young girls from imagining a career in such fields, because lack of role models limits their ability to see themselves in such sectors and prevents them from having individuals who resemble them and that they can mould their pathways on.

However, there are some positive developments in this regard: boys are more likely to see themselves following in the footsteps of their fathers, but girls are less willing to follow in the footsteps of their mothers. This is in part because the career opportunities available to the mothers of 15-year-old girls were generally not reflective of their potential ambition. This means that while boys tend to prepare to work in existing occupations, girls could be more easily attracted to explore becoming engaged in emerging sectors, such as ICT and technology rich sectors. This growing interest could be further reinforced by promoting female role models in STEM, who could further motivate girls to explore career paths that differ from those of their mothers.

Figure 32. Percentage of students who expect the same career as their parents, by gender



Notes: Students reported their expected occupation when they are 30 years old. Students' expected occupation and parents' current occupation are coded according to the International Standard Classification of Occupations, 2008 edition (ISCO-08), at the 3-digit level (e.g., 111 ISCO code: Senior officials and legislators). Countries and economies are ranked in ascending order of the percentage of boys who expect to have the same career as their father.

Source: Authors' own compilation based on OECD, PISA 2015 Database, https://www.oecd.org/pisa/data/2015database/.

The possibly annihilating effect of stereotypes and of role models on the relative ability of males and females in different subjects become apparent when examining the relative involvement of women and men in programming and coding from the birth of the modern computing industry to our days. At the beginning of the computing age, many of those involved in software programming were women, while men were more heavily represented in the hardware part of the computing sector. At that time, attention to details, patience and other characteristics seemed key to excel in programming, and the stereotype was that women excelled in such skills. Consequently, not only many women decided to work in the computing industry, but many were sought after by employers and were encouraged to work in that industry by teachers and orientation professionals. As the importance of software over hardware begun to emerge, the computing sector begun to project skills as creativity, complete dedication, social awkwardness as key ingredients of what it takes to be a great programmer and the stereotype of the "programming girl" morphed into the stereotype of the male "computer nerd" (Thompson, 2019).

Shaping education for technology and technology for education

The relationship between education and technology goes both ways. Understanding how to best leverage new technologies to support and enhance teaching and learning is key to live, learn and work in the digital era and to narrow the digital gender divide. As the Fourth Industrial Revolution unfolds (and the next AI revolution begins), education needs to understand how to make teaching and learning more efficient, effective and inclusive, and to help close the divides that exist, especially the digital gender divide. The ability of the Internet to reach and connect individuals in general, and girls and women in particular, in different parts of the world and to create virtual communities may help promote the integration of the disadvantaged. It may help provide them customised support, offer new opportunities that allow them to fulfil their aspirations (see OECD, 2018b).

Lifelong learning and technology: the importance of access, use and skills

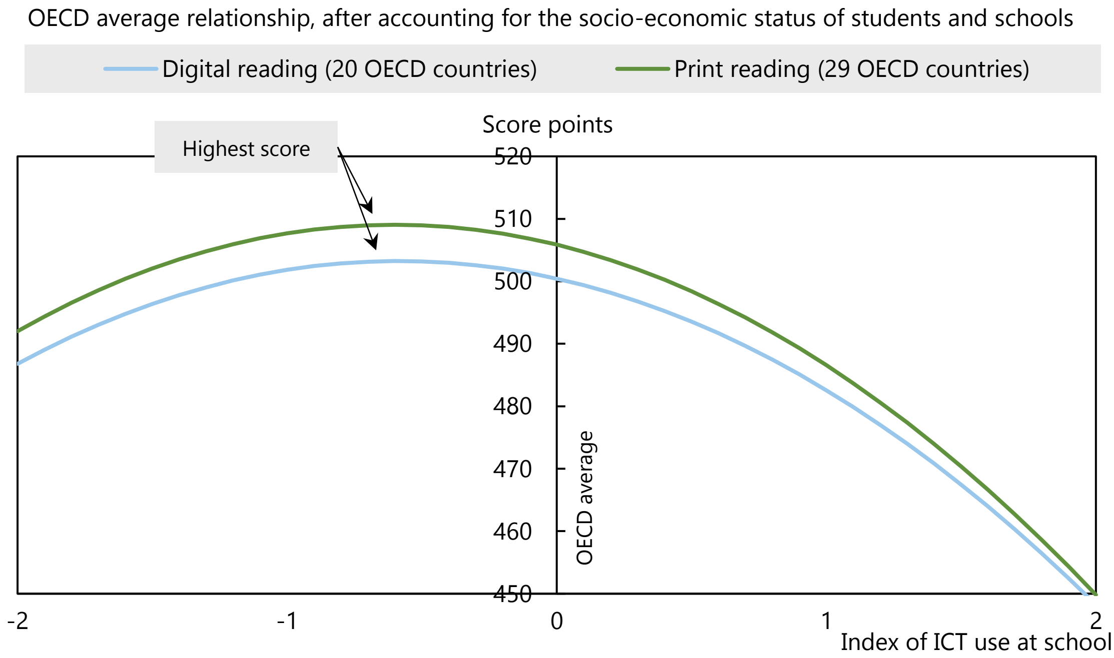
The use of technology in education is not only something that should be explored and implemented for the youngest cohorts of students, but also to support the lifelong learning of women of all ages. New technologies can be used to design and deliver flexible and customised learning arrangements which may help all adults, and women in particular, to learn, and foster both participation in different types of training, as well as the effectiveness of the training itself. This may be especially important in a new world of work where more fluid work arrangements, such as "gig" jobs, may lead to workers lacking of sponsors (as, e.g. fixed employers) who would provide training to them. This is especially important for women, given that digital platforms facilitate greater participation of women in the labour market as the flexibility that they entail may help men and women combine work and family responsibilities (OECD, 2018).

However, when it comes to using technology in education and fostering innovation in school, a number of hurdles emerge. Access to computers, the Internet and educational software can in fact offer important learning opportunities, empower boys and girls and promote their learning, in so far as the challenges entailed by the very use of technology are properly dealt with. On the one hand, the more time students spend online, the greater their exposure to online opportunities such as e-learning classes, seeking personal advice on issues that matter to them - such as gender, sex, health, identity and other issues (Hooft Graafland, 2018) - and online tutorials allowing them to acquire also practical skills (e.g. "how to" on YouTube). On the other hand, when boys and girls access digital content, they may also be exposed to inappropriate content, online bullying and gender stereotypical portrayals of men and women.

Evidence suggests that access to digital technologies can only be beneficial if students have the skills and the support needed to ensure that their use of digital technologies are mobilised to facilitate problem solving experiences and to create digital solutions rather than having simple, repetitive skill based experiences, and being potentially distracted by social media, online games or adverts.

Findings from PISA (2012, 2015) show a complex relationship between how much students use ICT at school and their performance in mathematics, science and reading: moderate use of digital devices at school may be better than no use at all, but ICT use above the average is associated with significantly lower results. In fact, students with the highest performance in both reading and digital reading use ICT slightly less than the average student does.

Figure 33. Students' skills in reading, by index of ICT use at school



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

Source: Authors' own compilation based on OECD, PISA 2012 Database, Table 6.2 in in OECD (2015c), Students, Computers and Learning: Making the Connection, PISA, OECD Publishing, http://dx.doi.org/10.1787/9789264239555-en.

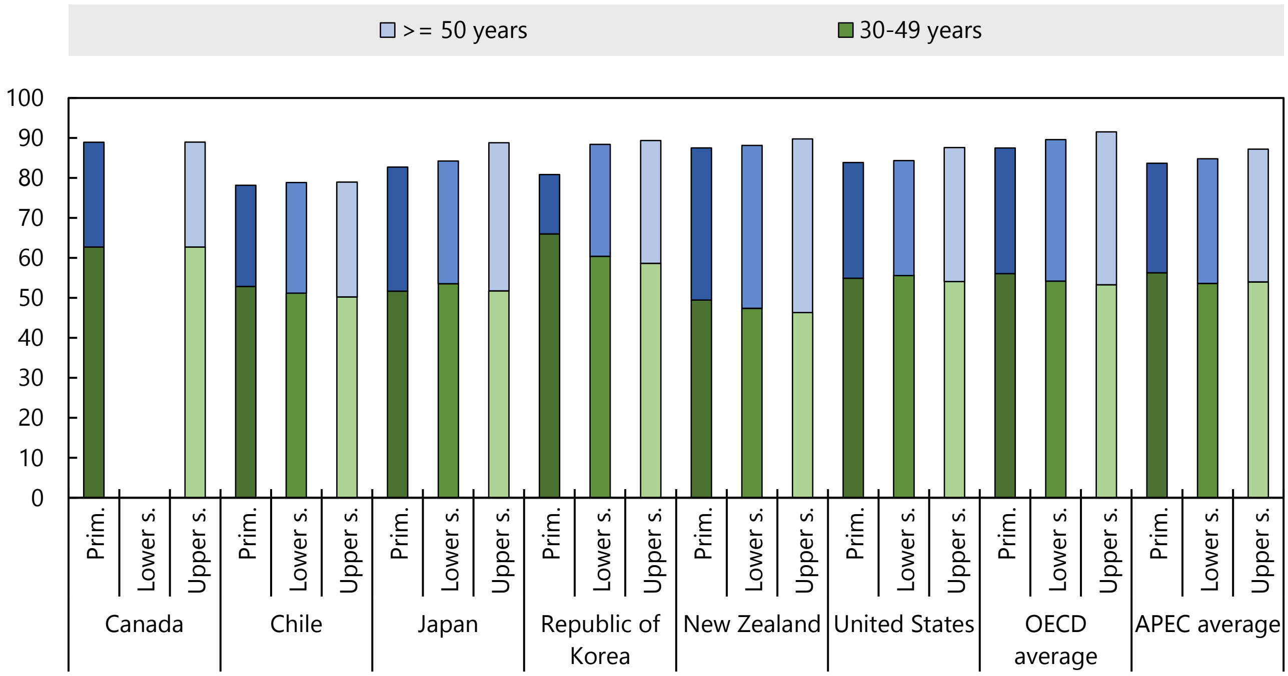
The role of teachers and teacher training

The complex association between use of ICT at school and student performance may have to do with teachers and educators receiving (or not) support and training on how to mobilise their knowledge and acquire the (new) skills needed to develop practical solutions and integrate digital components in school programmes. This can be the case both as standalone modules and as part of other subject matter teaching. Providing this support may entail the development of strong professional development opportunities for exiting teachers and integrating digital tools and skills in prospect teachers' initial education and training.

Evidence from Education at a Glance shows that in 2016 more than a third of teachers in compulsory education was 50 years old or older, with relatively greater shares of older educators being generally observed in higher levels of education. These educators were formed in an age when digital tools and opportunities where limited, if at all available, and virtually non-existent in educational settings.

Figure 34. Age distribution of teachers, 2016

Percentage of teachers in public and private institutions, by education level and age group, based on head counts



Notes: "Prim." stands for "Primary", "Lower s." for "Lower secondary" and "Upper s." for "Upper Secondary". Different shades of green are individuals aged between 30 and 49 years old (lower part of bars). Different shades of blue are individuals aged above 50 years old. APEC average based on data from: Canada (except "lower secondary"); Chile; Japan; Republic of Korea; New Zealand; and the United States.

Source: Authors' own compilation based on OECD Education Database available online at https://www.oecd.org/education/database.htm.

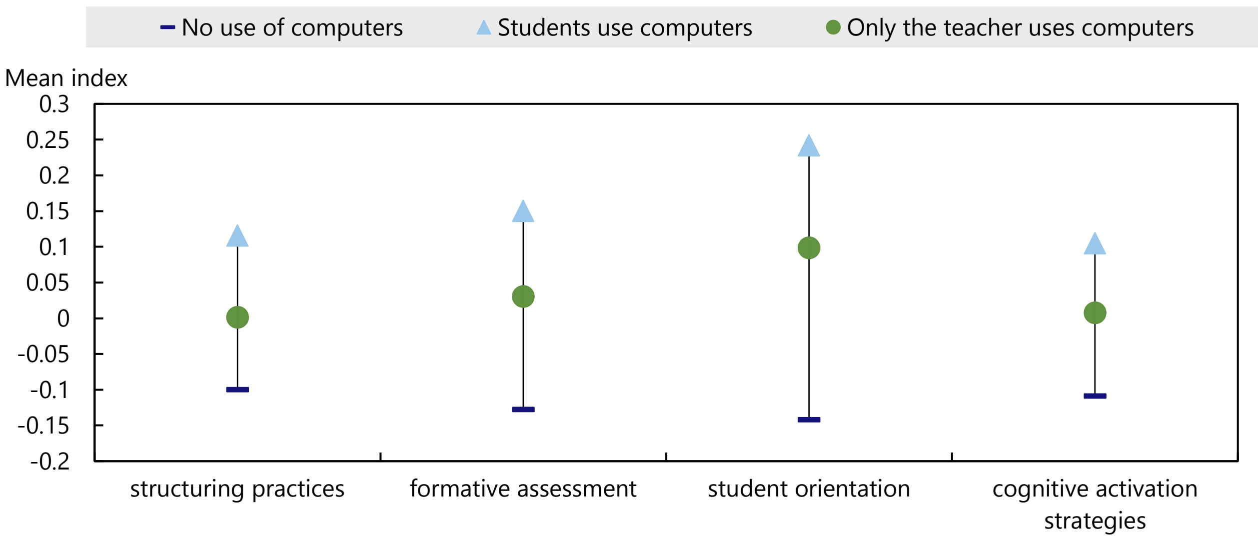
While age may contribute to explain the lack of digital-related skills, it is by no means the only cause. All teachers need to be endowed with the relevant digital-related knowledge and skills, if they are to pass these competences to their students and use these skills in a pedagogically appropriate way. Also, the speed, scale and scope of the digital transformation calls for a lifelong and life wide approach to teachers' continuous training, to upgrade and develop relevant digital-related training skills. Such training should not only be focused on the technology itself, but also on its use in a gender-neutral way and in order to help close existing digital gender divides.

From a gender perspective, integrating digital literacy in teacher training may encourage teachers to modify their approaches to teaching itself and help them reduce their adoption of stereotypical attitudes and transmit them to their students. The risk is that, if teachers are not competent users of digital technologies, they may avoid using ICT in their classes and fail to support their students become proficient digital learners. In addition, if they develop feelings of anxiety and uneasiness towards the integration of ICT in their classes, they may pass on such anxiety and uneasiness to their students. This is especially the case for female students, who already feel less confident in the use of technology than their male colleagues. Unfortunately, because many teachers are women, female students - but not male students - appear to be susceptible to feelings of anxiety among their teachers (Beilock et al., 2010).

Hence, it would be important to make teachers aware of the extent to which they may influence students, especially female students, with their anxieties, mindset and approaches, and have them develop an ability to recognise their own biases and stereotypes, to better support students – and girls in particular - fulfil their potential.

Figure 35. Teaching practices and disciplinary climate, by computer use in mathematics lessons

Mean indices (OECD average), Index of mathematics teachers' behaviour



Notes: All differences between students who reported "using computers during mathematics lessons" and students who reported "computers are not used" are statistically significant.

Source: OECD, PISA 2012 Database, Tables 2.13b, c, d, e and f in OECD (2015c), Students, Computers and Learning: Making the Connection, PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264239555-en.

There is evidence that teachers who use ICT for instruction tend to adopt pedagogical practices, instructional strategies and behaviours that are typically associated with better learning among students.

For example, data from PISA indicates that students who use ICT during mathematics lessons more often describe their teachers as frequently using structuring practices (e.g. setting clear goals, asking questions to verify understanding), student-oriented practices (e.g. giving different work to students who have difficulties or who can advance faster, having students work in small groups), formative assessment (e.g. giving feedback on strengths and weaknesses), and cognitive activation (e.g. giving problems that require students to apply what they have learned to new contexts and/or giving problems that can be solved in several different ways).

Current and future teachers and school leaders need to be supported to ensure that they effectively integrate ICT and digital content in the curriculum. They need to be and remain competent users of ICT and digital technologies themselves. They also need to know how to promote effective and responsible uses and engagement with ICTs among students (both in and outside of school), integrating ICT in school curricula. Doing so will ensure that curricula will best support students by ensuring that ICT becomes a tool to promote their cognitive development and well-being and enabling them to recognise and deal with digital threats such as cyberbullying, the trustworthiness of digital sources, and navigating digital content. Finally, they need to develop tools and strategies to effectively use these technologies for instruction, administrative and communication purposes, to ensure that they are able, through the use of ICT tools, to engage students in their class; parents in the educational progress of their children; and to exchange effectively educational material and advice with colleagues.

Teachers' capacity to use ICT resources for teaching and learning and for narrowing gender gaps in education depends on several contextual factors and practices and, crucially, relies on a multi-stakeholder approach, involving buy-in from all school staff, including school leaders, support staff as well as teaching professionals and educators within the school and local policy makers, industry leaders, parents' associations and youth associations from outside the school. Implementing curricula that maximize the benefit of ICT also depends on the availability and quality of ICT resources as well as other school-level policies and practices such as, for example, streaming and ability grouping[34]. For example, to the extent that initial level of proficiency in mathematics or interest in ICT is used to determine participation in advanced modules or classes promoting digital skills, gender gaps in digital literacy may be magnified because of existing differences in these factors.

[34] Ability grouping usually involves grouping students in a given year group into classes for specific subjects, but not across the whole curriculum while streaming usually involves grouping students into different classes for all or most of their lessons. Pupils in different groups often follow a different curriculum, particularly when different national tests, different examination levels or different types of academic and vocational qualifications are available. The aim of streaming and ability grouping is generally to facilitate teaching by creating homogeneous classes in terms of students' prior achievement.

It is important that teachers become active agents for change and engage in innovating and move away from considering their workplace as an essentially hostile-to-innovation environment, as it emerges from TALIS, the Teaching and Learning International Survey. Also, it is fundamental for education to help all individuals, and girls in particular, to take advantage of new tools and technologies while addressing concerns about misuse, abuse or any other possible drawback. This can be done by educating girls (and others) to use and shape technologies and to make them aware about what technologies can give us as well as what they can take from us. For instance, the way algorithms behind social media work tend to sort individuals into groups of people sharing common views and perspectives. This not only homogenizes visions, but also hinders the ability of individuals to learn about and discuss different perspectives, and tend to reinforce gender biases.

Teacher training and professional development is crucial if education systems are to be able to ensure that gender gaps in key skills and competences are bridged while increasing the proficiency of all. Yet, in many economies teachers and educators continue to struggle to promote students' engagement and motivation and ensure that children learn important skills that will be relevant for the labour markets and societies in the years to come. Finding ways to promote and sustain the motivation and learning of both boys and girls and ensure that girls are able to excel in mathematics, problem solving and digital skills but also that boys do not lag behind girls in text comprehension abilities is becoming an increasing priority for teachers, parents and educators. The fast paced and engaging nature of teenagers' leisure activities often stand in stark contrast with traditional classroom dynamics and teaching practices.

The digital transformation in the classroom

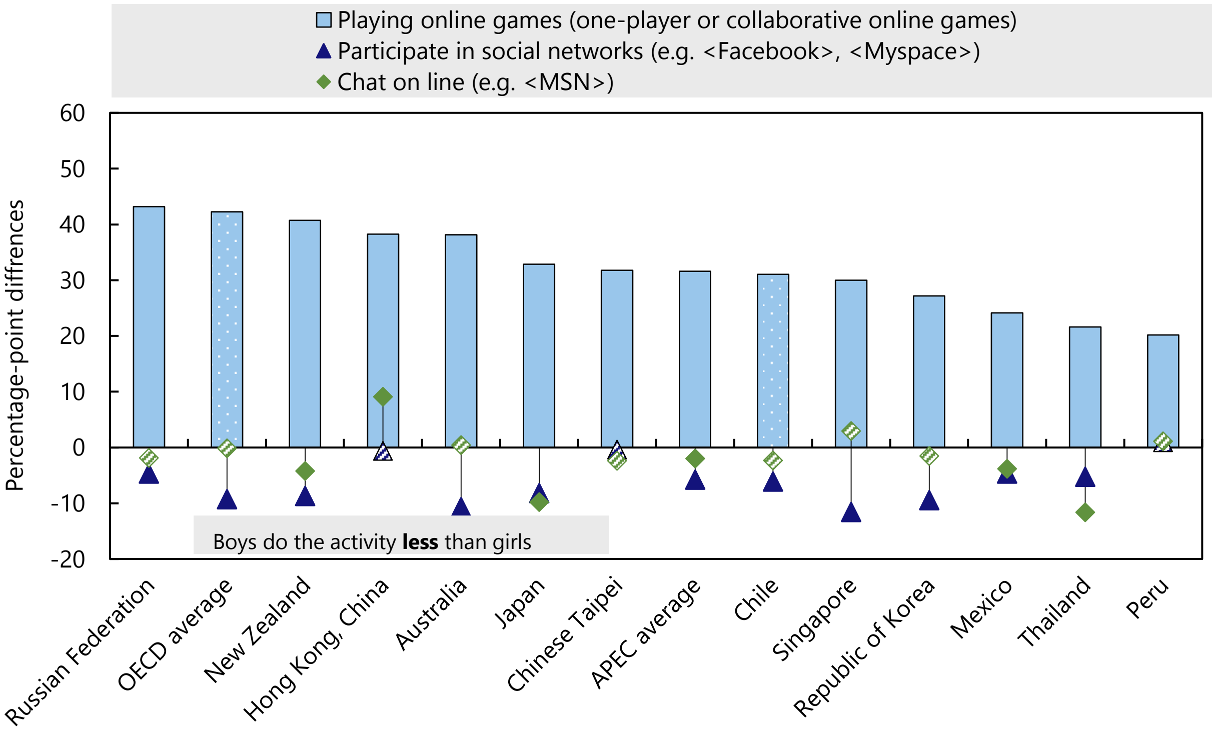
Education needs being prepared to change with technology and to provide students with the skills they need and will need on the job, in society or as citizens.

Many teachers and educators have still not adapted their pedagogical approaches and teaching methods to meet these demands and educational programmes are only beginning to integrate digital components and digital skills proficiency in their curricula. And just as many teachers in schools are not leveraging the potential of new technologies effectively, access to digital resources for learning purposes is not widespread in many economies. On average across APEC economies, the proportion of students with access to educational software at home increased from 35% in 2003 to 46% in 2006 and remained stable since then until 2015. The share of students with access to educational software at home in 2015 varied greatly across economies, ranging from 13% in Japan and 19% in Viet Nam to 80% in Australia among APEC economies. It was as high as 91% in Denmark, the OECD country participating in PISA with the highest penetration of educational software. Interestingly, even economies where more than 90% of students had access to the Internet and a computer at home showed relatively low access to educational software at home.

Research stresses the promising potential of computer-assisted learning to bolster student achievement (Roschelle et al., 2016; Pane et al., 2013; Karam et al., 2016; Campuzano et al., 2009). As the primary actors for implementing the curriculum and orchestrating learning activities, teachers are likely to be even more central to learning with the adoption of ICTs. Indeed, the success of using ICTs for educational purposes relies heavily on teachers' abilities to select, create and manage adequate digital resources in order to implement innovative and inclusive teaching strategies in a specific context (Redecker, 2017).

Figure 36. Use of ICT for leisure online activities, by gender

Difference in the percentages of boys and girls who play online games, chat on line or participate in social networks every day outside of school



Notes: Non-statistically significant values are in stripped bars. All differences for "playing online games" are statistically significant. Economies are ranked in descending order of the difference in the percentages of boys and girls who play online games. APEC average relies on 12 APEC economies, namely: Australia; Chile; Chinese Taipei; Hon Kong, China; Japan; Republic of Korea; Mexico; New Zealand; Peru; Russian Federation; Singapore; and Thailand.

Source: Authors' own compilation based on PISA 2015 Database, Table III.13.13.

Educate students for their future, rather than based on the past

Schools have a certain degree of conservativism engrained in them, with changes and innovation in education that generally take a long time to be accepted and translate into practice, for a number of reasons. These include the interest, beliefs, fears and motivations of the people involved in education, including teachers, parents and politicians, which tend to sustain and reinforce gender disparities in educational outcomes.

Teachers may be unsure about or have a hard time delivering the (new) knowledge and implementing the (new) pedagogical approaches they were thought or learnt. Also, they not always are convinced that every student can learn and tend to conform with and consequently act according to socio-economic status-based expectations. In addition, teachers may not feel empowered in their function, nor sufficiently valued or respected by society.

Parents generally feel unsure when children learn what they do not know, or do not think is important for them, or do not study what they think is important.

In addition, educating children for the future entails dealing with the development and adoption of new technologies, and in particular with the speed, scale and scope of digitalisation. Digitalisation is rapidly changing the way people connect, live, work, act and, of course, learn. It facilitates accessing information while requiring at the same time a sound ability to navigate a huge amount of content to find the relevant information and discard false or deviating information. Digitalisation facilitates connections and can help the democratisation of knowledge, while at the same time allowing for the polarisation and concentration of knowledge and information, and for widening gaps, including the gender divide. Children (and individuals of all ages, in fact) need to learn how to deal with, and be able to distinguish, what is "right" from what is "wrong", but also how to question stereotypes and societal "values" that are not inclusive, as those underpinning the gender divide. There is nothing pre-determined about the way technologies affect people's life, as outcomes ultimately depend on the way societies, culture and institutions, among others, respond and behave, and the ability of individuals to learn how to learn in a changing environment.

Finally, making children "future-ready" means making them able to be citizens of a globalised world and have global competencies, i.e. being able to examine issues of local, global and cultural significance, and gender, race, class etc. -neutral in their behaviours. Children further need being able to integrate subjects and learning contexts; and developing an ability to co-create knowledge with others and to develop synergies. Moreover, to do this, educational systems need, among other things, to become able to personalise and customise educational experiences, thus engaging students and fostering their talents. Ultimately, addressing the gender's educational divide, digital and not, is key for economies to achieve gender equity and empower all women and girls, as stated in the Sustainable Development Goal number 5, adopted in New York in September 2015 in the context of the United Nation Summit (UN, 2017).

Meet the education and skills needs of the digital era while avoiding curriculum overload and addressing gender divides

We often hear complains about education systems not being able to provide the skills that students need in the real world or in the world of work, including the skills needed to thrive in the digital world and that would allow women to fully participate and excel in the Fourth Industrial Revolution. Companies often complain about not being able to recruit professionals having the full spectrum of skills they need, especially the socio-emotional skills and task-based skills needed on the job, and having to train newly recruited staff ahead of having them starting to work. In this respect, five areas for policy relevant educational research have been identified in the context of the OECD Education 2030 project, namely:

1) How to improve the quality of learning instead of extending learning time, and how to avoid curriculum overload despite the call for a greater number, type and quantity of subjects asked to be included in education? And how to make education more inclusive and less gender biased?

School systems differ in the time that students spend learning, inside and outside school. While at the within economy level, more learning time generally leads to better results (if the quality of education is held constant), comparing results across economies shows that economies with relatively longer learning time generally perform comparatively worse in PISA (OECD, 2016b). This highlights the importance of both quality and quantity of learning opportunities, especially for girls and young women, and suggests that improving the quality of instruction may lead to increasing educational outcomes without necessarily extending learning time.

2) How to incentivise students to engage in the required learning and have teachers deliver unbiased teaching of high quality? How to foster the deep understanding that education is expected to endow individuals with, regardless of gender?

Motivation, empowerment, and co-decision are among the incentive mechanisms that policy may try to leverage upon, together with better rewards and greater recognition.

3) How to ensure that teaching and learning quality remains high while innovating? When it comes to innovation, it is important that change, also technological one, is for good and that curricula and innovations ensure equity and inclusiveness, and allow all students to benefit, independently of their social or economic background and their gender. In some cases the innovations needed or sought may be "architectural" (Abernathy and Clark, 1985) in nature, in the sense of requiring a complete overhaul of (at least part of) the education system.

4) How to carefully plan and align goals, so that education reforms are implemented in an effective and efficient way? International evidence shows that implementing curriculum reforms successfully requires also targeting complementary policy areas, such as assessment practices and support and training for teachers, as discussed above.

5) How to reduce the time lags existing between recognition, decision-making, implementation and impact? At present, the gap between curriculum intent and learning outcome appears generally too wide and by the time reforms are implemented they may already be obsolete and unable to address the very challenges they are supposed to deal with.

In addition to the above, it would be important to embed programme assessment in the design of education policies, to be able to constantly monitor progress and hurdles, and to adjust design and re-tailor efforts when needed. The technologies available in the digital era and the possibility to collect and analyse real time and “big” data might help in this respect, especially when the goal is to keep track and steer policies aimed at narrowing the gender divide in all its forms, including the digital gender divide.

Also, for curricula to better meet the needs and desiderata of everyday life, society and work, and in order to make of education the place where gender biases end, it is important to involve different stakeholders in the design of education and learning systems, including educators, companies, and families. A fundamental element is also to try to balance the development of knowledge, competencies and values for students and to ensure that teachers use active learning strategies. Finally, in a world becoming all the more intertwined, it is important to adapt curricula, instructions and assessment methods as well as organisational culture of educational settings to reflect cultural diversity, while getting rid of inherent gender biases and socio-cultural norms discriminating against women.

Finally, yet importantly, succeeding in teaching new and different skills, including socio-emotional skills like self-confidence, resilience, teamwork and commitment, without increasing studying time may be achieved through using different pedagogical approaches when imparting subjects already in the curriculum. Mastering these skills is crucial to succeed in the labour market and in life for both men and women and therefore should be taught to both genders. However, at the moment women appear to lag behind men because of the many and complex factors examined in this report. Using pedagogical approaches that foster inclusion when imparting curricular subjects would help remove gender biases, both through the very knowledge shared and the way in which it is conveyed.

Enhancing educational outcomes while reducing inequalities and fostering inclusion

Better overall performance of education and training systems is something that all economies are striving to achieve. Improving performance often requires innovating, in an incremental or in a radical fashion. Long-standing evidence related to technological innovation and firm productivity shows that innovators typically represent a relatively small and selected subsample of the overall population (e.g. firms, universities). In addition, policies aimed at improving innovation and performance (e.g. R&D subsidies) may end up “picking the winners”, thus reinforcing the distance that exists between the best versus the rest.

Transposing the lessons learnt in industrial and innovation policy to education and learning implies that, to avoid increasing existing divides, policies fostering educational innovation and performance need encompassing actions aimed at reducing disparities and actively supporting inclusion, also and especially gender-related. It is important to reduce disparities between the most and least advantaged schools (e.g. in poor neighbourhoods, in rural areas) and to distribute resources across schools, as equity can be undermined when students and schools are matched based on socioeconomic background. Socio-economic status and gender often interact to shape individuals' learning trajectories.

Evidence shows that it is more important how education money is spent, rather than how much money is spent. Results from PISA indicate that the quality or learning outcomes is not at odds with equity and inclusion in the distribution of educational opportunities and none of the economies stratifying students by ability (differently defined) appears amongst the top performers in PISA. As such, the level of spending per student matters on the lower part of the distribution (i.e. up to USD 35 000 per student, between the age of 6 and 15), but that there is no relationship between spending per student and the average student performance beyond that spending level (OECD, 2016b). Greater equity in the distribution of resources goes hand in hand with increased local economy-level performance, and some economies e.g. Germany, have succeeded in raising overall achievement levels while at the same time reducing differences related to socioeconomic backgrounds and addressing divides.

How to shape up the education profession and make teaching more inclusive when budgets and motivation are low?

Educators are key for learning. If students are to be thought new or different subjects and concepts or need to acquire new, different and better skills, it is important that teachers are able and willing to teach them these in the first place. This, however, is not a given, for a number of reasons, which reinforce each other.

In some economies, the teaching profession has been suffering for years from some sort of "adverse selection", in the sense that the education system has not been able to attract the most talented or best performing human capital. This is due to some degrees to the progressive erosion of the purchasing power and of the social recognition of the profession observed over the last years. While in top performing economies, education-wise, teachers are generally recruited from the pools of top performers in tertiary education, in other economies, teachers and educators are drawn from the central and lower end of the performance distribution (see also Hanusheck et al., 2019). Also, between 2005-14 the salaries of teachers basically stalled, in real terms (+1%), and decreased in one-third of OECD countries, thus ending up with upper-secondary teachers that currently earn about 90% of what other tertiary-educated workers earn. Evidently, this can hardly motivate best performers to enter the profession.

Much is expected from teachers against this drawback of relatively low salaries. They should have the necessary professional knowledge (i.e. of the topic, the topic's curriculum and related pedagogical approaches maximizing knowledge acquisition) and be able to create the sort of learning environments that are more conducive to good outcomes. Passion, compassion and thoughtfulness is also expected from teachers, together with an ability to deal with different types of needs and characteristics, including gender and socio-economic backgrounds. Teachers are also expected to master all the types of proactive, collaborative and socially enhancing skills and abilities that we would expect them to teach to their pupils, and to be inclusive.

This is important also because PISA finds that a negative relationship with their teachers undermines students' feeling of belonging at school. Students reporting that their teachers are willing to help and care about their learning are 1.3 times more likely to feel that they belong to school. Teachers need to know how to help students understand their strengths and weaknesses, and help them address the latter, as otherwise students may internalise mistakes as meaning that they are not smart enough, which is something that girls are particularly good at doing, unfortunately. Negative teacher-student relationships may undermine students' confidence and lead to greater anxiety.

Finally, yet importantly, teachers are expected to have the inquiry and research skills that would allow them to continue learning over time and to grow professionally, and to be ready to change their beliefs and be willing to try new approaches, especially those agreed by the profession as effective.

While these problems are very much interrelated, trust and ownership can go a long way. It is important to make of teaching a more attractive and well-respected profession, and to give teachers more responsibility, independence and access to quality training. When teachers themselves contribute to decide about what to improve and discuss collaboratively on how to improve things, it may become easier to raise standards for the profession. This has been proven e.g. in the case of the Netherlands. In addition, teachers may be more willing to be assessed if consulted in the process and involved in deciding teaching standards.

In addition, it is important that both teachers and students are not "victims" of dysfunctional schools. To this end, a number of interrelated leadership responsibilities are key. These include: the need for school leaders to support, evaluate and develop teacher quality; establishing learning objectives and assessment designed to help students achieve high standards; using resources in a strategic fashion and having pedagogical approaches align with the objectives set; fostering cohesion among all agents shaping the achievement and well-being of children, inside and outside schools.

When education systems and school leaders are able to promote and support high levels of professionalism and proficiency among teachers, giving them autonomy is often associated with better student performance. This positive association, however, depends on the presence of clear and well-defined accountability frameworks, shared goals and standards and clear guidelines that are shared throughout the system on goals and objectives. Giving teachers and schools autonomy to experiment on how best they can reduce gender gaps in digital literacy proficiency may help narrow gaps. This is the case if autonomy is accompanied by effective and transparent accountability and monitoring frameworks, and by a system designed to share information on what works and what does not work.

Designing an approach to promoting digital proficiency

A comprehensive approach to promoting digital proficiency should encompass a number of key competence areas (Redecker, 2017; Fraillon, Schulz and Ainley, 2013; Fraillon et al., 2015), including:

- accessing, evaluating and managing information and data,
- sharing information and communicating,
- transforming and creating digital content, and
- individual and collaborative problem solving in a digital context and computational thinking appropriate use of ICTs, which embeds knowledge and skills related to security, safety and risk awareness

Besides the development of an effective policy and technical infrastructure to support digital learning among students, school systems could develop guidelines to support digital proficiency organised in such a way as to sustain the following principles:

Reduce gender gaps in foundation skills that are needed in a digital environment

In a world that is rapidly embracing digital technology as the main medium of communication, students need to learn how to gather and use online information. They must be familiar with the text formats encountered online in order to learn to navigate through the web critically and successfully. As a matter of fact, the typical texts encountered online require certain reading abilities, such as evaluating the trustworthiness of sources, drawing inferences from multiple texts, and navigating within and across pages, more than it is required with traditional printed texts. All of these abilities can be learned and practiced in school settings.

The increasing importance of reading and writing in daily life is one of the reasons why the benefits of digital technologies are unevenly shared across high-skilled and low-skilled individuals and by gender. In addition, the fact that computers and digitally enhanced machines, or robots, can perform many tasks at a lower cost than human workers means that the skills that complement new technologies are in increasing demand. The greatest benefits accrue to those who have the ability to design digital solutions, adapting or creating machine algorithms to fit one's needs and, more generally to perform tasks and cognitive functions that represent a complement to what machines can do. These capacities build on advanced reasoning and problem-solving skills and require good mastery of symbolic and formal language. They often build on related skills acquired in mathematics courses, where girls generally – although by no means universally - underperform compared to boys (OECD, 2018b).

Reading in the digital medium builds on reading skills acquired in a non-digital environment, but also relies on good navigation skills. Navigation, in turn, requires an awareness of what is known and what is not and the ability to act upon this knowledge; the ability to organise complex hypertext structures into a coherent mental map; experience in evaluating the relevance of pages; and a repertoire of effective strategies for reading on line. Without these, students find themselves digitally adrift. Girls and women tend to underperform in these areas, as discussed in chapter 2.

The most successful economies in the PISA digital reading assessment have similar visions of the importance of digital skills for today's students (OECD, 2015c). But they differ in the level of use of information and communication technologies in schools. Singapore and the Republic of Korea, two of the highest-performing economies in digital reading and among those economies where the quality of students' web-navigation behaviour is highest, have excellent broadband infrastructure (ITU, 2014) and high levels of familiarity with computers among 15-year-olds students. Yet students are not more exposed to the Internet in school than are students on average across OECD countries. Despite this, most students have a good mastery of the strategies that assist them in online navigation – in addition to performing strongly in all domains assessed in PISA. This suggests that many evaluation and navigation skills may be acquired more easily if students are already proficient in higher-order thinking and reasoning processes in other domains.

In Australia, another high-performing economy where students demonstrate strong ability in browsing the web, the Internet is used during school hours to a greater extent than in any other economy that participated in the optional ICT familiarity questionnaire in PISA 2012. ICT is represented in two ways in the Australian Curriculum – within the "Technologies learning area curriculum"; and through the "ICT general capability", which is embedded across all learning areas of the curriculum. The learning continuum for the ICT general capability describes the knowledge, skills, behaviours and dispositions that students can reasonably be expected to develop at particular stages of schooling. This framework guides teachers and industry in creating the educational resources that promote proficiency in the use of electronic sources of information. It further helps to ensure that students develop useful skills in their time online, such as planning a search, locating information on a website, evaluating the usefulness of information, and assessing the credibility of sources. The extent to which these general principles need to be adapted to take into account the specific skills, preferences and expectations of female students is not known and remains to be determined.

Raise awareness of the possible benefits and harmful aspects of Internet use

Digital means may be very empowering for women, by offering them new or different information and learning opportunities, by allowing them to participate in the labour market (to a greater extent) and by granting them flexibility, facilitating new entrepreneurial endeavours and so on. However, the large prospective benefits of the digital era may be counterbalanced by a number of threats that digital means can present.

When every child has access to the Internet, parents and teachers can use the educational resources that are available online to foster children's learning. Yet unlimited access to the Internet can also have negative consequences for children's development. Those in charge of educating today's "connected" learners are confronted with a number of new (or newly relevant) issues. These encompass "information overload"; plagiarism; protecting children from online risks, including fraud, violations of privacy and online bullying, which disproportionally affect as victims girls and women; and setting an adequate and appropriate media diet (OECD, 2012a; OECD, 2014). Previous studies had found negative impacts of extended screen time on adolescents' sleep (Cain and Gradisar, 2010; Hysing et al., 2015), physical activity (Melkevik et al., 2010) and social well-being (Richards et al., 2010). Based on the available research evidence, several local public health authorities have warned about the possible negative consequences of increased screen time (e.g. House of Commons Health Committee, 2014, p.85) and issued guidelines that recommend limiting children's recreational screen time, typically to less than two hours per day (e.g. Council on Communications and Media, 2013; Population Health Division, 2015). Parents, schools and health professionals can work together to monitor and plan children's use of new media, especially in the case of girls – as risks may be higher.

Schools should educate students as critical consumers of Internet services and electronic media, helping them to make informed choices and avoid harmful behaviours. They can also raise awareness in families about the risks that children face online and how to avoid them (OECD, 2012a). In addition to protecting children from online threats, parents must help children to balance leisure uses of ICT with time for other recreational activities that do not involve screens, such as sports and, equally important, sleep.

Develop coherent plans, including teacher training, for using ICT in the classroom

Plans for technology in education sometimes promise to improve the efficiency of education processes, delivering better results at lower cost (OECD, 1999; OECD, 2010). Yet the link from more technology to better results is far from direct, and many actors need being involved in order to make the required changes happen. The costs to be incurred are not limited to the devices that need to be bought; they include teachers to train, resources to be developed (including digital material), infrastructure adaptation (e.g. buildings), as well as the foregone benefits of alternative uses of that money (the so-called opportunity costs). Evidence from PISA shows only a weak or sometimes negative association between the use of ICT in education and performance in science, mathematics and reading, even after accounting for differences in domestic-level income and in the socio-economic status of students and schools.

In most economies, students who make some use of the Internet at school, for instance, tend to be better at reading, particularly when it comes to understanding and navigating online texts, than students who never browse the Internet for schoolwork at school. But other activities, such as using drilling and practice software for mathematics or languages, show a clear negative relationship with performance. And more frequent, daily browsing of the Internet at school is also generally associated with lower performance (Australia is a rare exception to this pattern). The most rigorous impact studies also show no effects of investments in computers on students' non-digital performance. While there is too little credible evidence on this issue, positive findings are limited to certain contexts and certain uses of ICT. These include when computer software and Internet connections help to increase study time and practice, or allow teachers to provide optimal learning opportunities to students, in which students assume control over their own learning and/or learn collaboratively.

Schools and education systems are, on average, not yet ready to leverage the potential of technology. Gaps in the digital skills of both teachers and students, difficulties in locating high-quality digital learning resources from among a plethora of poor-quality ones, a lack of clarity on the learning goals, and insufficient pedagogical preparation for blending technology meaningfully into lessons and curricula, create a wedge between expectations and reality. If these challenges are not addressed as part of the technology plans of schools and education ministries, technology may do more harm than good to the teacher-student interactions that underpin deep conceptual understanding and higher-order thinking.

While these principles are applicable in general, they are particularly relevant when issues of inclusiveness in education are considered. Closing the gender gap in the digital era crucially depends on the development of strong curricular frameworks tailored to the needs, abilities and expectations of girls and women, considering contextual factors and leveraging on the inclusive power of new technologies.

Women and the aging population in the digital era: the importance of lifelong learning

While educating new cohorts of girls for the digital transformation is important, the full weight of the impact of technology on gender equality should be appreciated in a life course perspective. The demographic transformation which tends to increase the life expectancy of individuals, and of women in particular, coupled with rapid technological change, calls for the development and provision of lifelong learning opportunities. These should also address the needs of older cohorts of women, who in many economies have low familiarity with digital means, but also low levels of foundation skills.

This calls for rethinking lifelong education both as a "right" and as a "duty" of all citizens – especially women - and for the need to start education very early in life and continue it throughout the life course of people. Recent evidence shows that, for instance, some socio-emotional skills that are much needed and demanded in today's world are acquired at very young age. However, these skills depreciate if not used and sustained and can also be acquired later in life - albeit at the cost of greater efforts.

Redesigning education and learning as a lifelong companion of people nevertheless poses a number of conceptual and operational challenges, which are far from being resolved. Among them which skills to teach at which stage; how; and to what extent and how adults learn. Relatively little is in fact known about the effectiveness of different types of adult learning and training, and whether and how experience can help make up for the cognitive abilities that may have depreciated over time.

Another question that educational research would need to answer is which balance to strike between specialisation and flexibility, in terms of educational paths. In today's world, specific expertise may be highly rewarded and may represent a competitive advantage on the labour market. However, also due to the fast pace at which technology and the world of work are changing, the specialisations demanded change. Hence being extremely specialised may mean risking to be "locked in" a profession or job that disappears (e.g. because of automation), or being unable to change educational path over time. For example, a trade-off generally characterises high school vocational education. The possibility to learn readily deployable occupational skills may come at the expenses of the educational and career flexibility afforded by general academic courses, and policy is experimenting how to address such a trade-off.

Bertrand et al. (2019) for instance study the effects of a nationwide high school reform in Norway (so called "Reform 94"), which aimed at integrating more general education into the vocational track. They find that the reform succeeded at improving social mobility, particularly among men, but it somewhat exacerbated the gender gap in adult earnings. This confirms that the impact of policy changes may be diverse and have inequality effects that had not been foreseen.

Chapter 4

WHAT ROLE FOR POLICY?

MAIN CONCLUSIONS AND POLICY IMPLICATIONS OF THE ANALYSIS

This chapter discusses the possible role of policy, as emerged from the analysis in the other sections. It compounds the key policy lessons, implications and recommendations that policy makers may consider implementing in APEC economies to bridge the gender digital divide.

Mapping key policy recommendations for APEC economies

What follows synthesises the key findings and policy implications emerging from the report, each time highlighting the role that education and education systems can play in narrowing the digital gender divide.

Access to and ownership of digital means and access to (good quality) education are the only key enabling factors not discussed in what follows, as they represent necessary preconditions. At present, APEC economies differ substantially in both and action to promote them relies on a wide range of policies, including but not limited to education.

In addition, as it happens in any policy domain, measures aimed at closing the digital gender divide need to be tailored to the unique context in which they will be implemented. This, in turn, requires consideration of different factors, such as the development level of the economy or the targeted area, regional differences, disparities across urban and rural areas, the demographic and social profiles of the relevant populations, the institutional settings and regulatory frameworks, as well as the interactions among all of these factors.

Moreover, while representing important elements of a coherent strategy, the policy implications outlined here may differ in the complexity of their design, in the timing of their possible implementation and in the cost, they may entail for governments and for other stakeholders involved. In addition, it is important for policy design and implementation to take into account the interactions and possible complementarities that may exist between different measures.

Table 1 gives a preview of the key policy actions derived from the evidence presented in the report. Such actions are grouped along two important dimensions: the time it may take to design and implement the measures considered, and the possible cost that governments may need to sustain in order to implement them.

Time wise, three horizons are considered: short term (up to five years); medium term (between five and ten years); and long term (ten years or above). Cost-wise, policy actions are grouped into “low”, “low to medium”, “medium to high” and “high” cost measures. These costs need to be understood in relative terms, i.e. in relation to each other, as a sort of a ranking of what may be relatively more or less costly. Moreover, in the real world, the very same policy action may command lower or higher costs, depending on a number of structural and contextual characteristics, such as those highlighted above, and on the type and quantity of stakeholders that governments may leverage upon (e.g. companies, private institutions, ONG, international organisations, and so on).

While this is not explicitly considered, it is crucial to highlight how, given the severe economic and social penalties associated with the digital gender divide, the cost of action is likely to be several times lower than the foreseen cost associated with inaction. The latter may potentially worsen conditions for women in the digital economies of the 21st century.

Low-cost short-term policy actions should be considered as a "must do" for economies that intend to reduce the digital gender divide: these are actions that could be implemented in a short time frame and at relatively low cost for governments, often simply by legislating in the right direction. They are important not only because they can have an "immediate" impact, but also because such impact can be achieved even in a context of scarce resources and budgetary constraints. The demonstration effects that they may have can also motivate (other) stakeholders and the broader public and, by so doing, sustain the political will to engage in longer-term actions and initiatives. "Must do" actions could be complemented by others, which can be considered "low hanging fruits", i.e. actions that can be implemented in a relatively short to medium time horizon at low to medium costs.

At the other hand of the spectrum there are policies that could be defined as "strategic and structural". These are policy actions which might entail important budgetary commitments for non-negligible periods, and that are likely to bear (very important) results in the long term, mainly. These strategic and structural policy measures are also those which could help close the gender divide, including the digital one, once and for all.

It is also important to underline that the list of policy actions below is by no means exhaustive, as it derives from the evidence proposed in the present report, which, in turn, is mainly centred on education and skills-related issues. Many other policy actions may be needed to address other facets of the digital gender divide, e.g. the involvement of women in innovative activities and software development as done in OECD G20 report (2018), or the way in which the digital transformation may exacerbate the divide already existing in the analogue world.

Finally, the need to innovate, include, engage, act and monitor in a timely fashion represents an overarching policy item, which would need to be implemented in a continuous fashion. Its cost will depend on whether such a proactive approach is already factored in at the design phase of policy measures or, conversely, as an ex post element, which is added once policy actions are already being implemented. Monitoring by design is generally cheaper and much more effective than ex-post assessment, and allows revising policies in a timely fashion, if needed. Digital tools and means may represent an important asset in this respect and may help collect and analyse a wealth of relevant data.

Table 1: Typifying key policy actions: implementation time and cost for governments

Cost for government	Time frame from design to implementation		
	SHORT	MEDIUM	LONG
LOW	Make teachers aware of gender biases and being role models for students		
	Make educational material and approaches gender neutral		
	Stop online violence		
	Get girls to code: bring girls and software closer		
	Address self-censorship and make girls aware of real abilities		
	School to engage with parents to shape expectations about future		
		Fix the leaky (STEM) pipeline	
	Close the gender wage gap and address age-based discrimination		
LOW TO MEDIUM		Key role of school leadership	
		Break the (vicious) circle of lack of self-confidence and of information	
		Bundle cognitive and socio-emotional skills in curriculum design	
		Endow girls and women with the skills needed for the future of work	
		Plan to align expectations with reality and engage stakeholders throughout	
MEDIUM TO HIGH	Use ICT at school (with moderation) to optimise learning		
	Get women to work side by side with machines		
		Teachers as active agents for change	
		Make girls future-ready: digital literacy and global competence	
			Design and shape lifelong learning opportunities, also for occupational transitions
HIGH	Address time poverty and provide childcare and family support		

Source: Authors' own compilation.

In what follows, the policy implications listed in Table 1 above are outlined starting from a skill-related perspective, followed by a discussion centred on educators and their role, and by a focus on attitudes, expectations, discrimination and violence. Finally, the importance of a systemic policy approach is highlighted.

ICT use, skills and learning: Make it happen!

Use ICT at school (with moderation) to optimise learning

The most successful economies in the PISA digital reading assessment have similar visions of the importance of digital skills for today's students. However, they differ in the level of use of information and communication technologies in schools. A complex relationship emerges between how much students use ICT at school and their performance in mathematics, science and reading.

Moderate use of digital devices at school may be better than no use at all, but ICT use above the average is associated with significantly lower results. Also, access to digital technologies can only be beneficial if students have the skills and the support needed to ensure that their use is mobilised to facilitate problem solving experiences and to create digital solutions rather than having simple, repetitive skill-based experiences, and being potentially distracted by social media, online games or adverts.

Extreme video gaming, compulsive texting and overuse of smartphones can have serious physical, social, psychological and cognitive consequences and impede learning. Excessive use of ICT also undermines motivation and academic achievement, can lead to social isolation and depression and can hinder the development of important cognitive and non-cognitive skills.

Let's get girls to code: bringing girls and software (use and development) closer

Women not only use the Internet less than men; they also use and develop less software applications. Even when they know about digital technologies, women are found to be less confident in actually using them. This is worrisome as contributing to create or shape digital content and tools is key to designing a digital future that accounts for women's needs and desiderata.

Education curricula should aim to make both boys and girls aware of and, to the extent possible, familiar with some key new technologies and with software use and development. Also, it would be important to make girls and women understand the possible risks arising from male-only or men-mainly driven innovation and to make them more aware of the potential benefits that the Internet may bring, including labour market participation possibilities.

Make girls future-ready: digital literacy and global competence

In a world that is rapidly embracing digital technology as the main medium of communication, students need to know how to gather and use online information. Children (and individuals of all ages, in fact) need to learn how to deal with, and be able to distinguish, what is "right" from what is "wrong", but also how to question stereotypes and societal "values" that are not inclusive, as those underpinning the gender divide. There is nothing pre-determined about the way technologies affect people's life, as outcomes ultimately depend on the way societies, culture and institutions, among others, respond and behave, and the ability of individuals to learn how to learn in a constantly changing environment. Children, and girls in particular, further need being able to integrate subjects and learning contexts; and developing an ability to co-create knowledge with others and to develop synergies.

Making children "future-ready" means making them able to be citizens of a globalised world and have global competencies, i.e. being able to examine issues of local, global and cultural significance, and being gender, race, class etc. - neutral in their behaviours.

Bundle cognitive and socio-emotional skills in curriculum design

Analysis about the skills that are most in demand in today's labour markets show that workers need to be endowed with a solid set of cognitive skills, including ICT-related skills such as computer programming, coupled with soft skills including communication skills, planning skills and teamwork / collaboration skills. Further, succeeding in teaching new and different skills, including socio-emotional skills like self-confidence, resilience, teamwork and commitment – some of which are extremely important for women - without increasing studying time may be achieved through using different pedagogical approaches when imparting subjects already in the curriculum.

This would need to be reflected in the design of educational curricula at different levels of education while avoiding curriculum overload or (too) extended learning time, as economies featuring relatively longer learning time generally perform comparatively worse in PISA.

Endow girls and women with the skills needed for the future of work

Men and women differ, on average, in the level of the skills they possess and different types of skills matter to different extent in different occupations. On the labour market, men tend to generally display relatively better numeracy, also advanced numeracy, management and communication and problem solving in technology rich environments skills. At age 15, girls tend to under-achieve in problem solving tasks compared to their male counterparts. Crucially their underachievement in problem solving is more severe than what could be expected given girls' curricular performance and is concentrated in knowledge acquisition tasks rather than knowledge utilisation tasks. Taken together these results suggest that girls may be lagging behind boys precisely in the aspects that are crucial to play an active and leading role in the digital era.

It would be important for education, also lifelong education, to address the root causes of this gender-biased performance and to identify educational approaches allowing girls and women to perform as well as they do in other subjects.

Getting women to work side by side with machines: what does it take?

In the Fourth Industrial Revolution, the greatest benefits are likely to accrue to those who have the ability to design digital solutions, adapting or creating machine algorithms to fit one's needs and, more generally to perform tasks and cognitive functions complement what machines can do. These capacities build on advanced reasoning and problem-solving skills and require good mastery of symbolic and formal language. They often build on related skills acquired in mathematics courses, where girls generally – although by no means universally - underperform compared to boys. Reading in the digital medium builds on reading skills acquired in a non-digital environment, but also relies on good navigation skills. Navigation, in turn, requires an awareness of what is known and what is not, and the ability to act upon this knowledge; the ability to organise complex hypertext structures into a coherent mental map; experience in evaluating the relevance of pages; and a repertoire of effective strategies for reading on line. Without these, students find themselves digitally adrift and girls and women tend to underperform in these areas.

Education should try to cater for the different digital needs of boys and girls and foster the acquisition of the skills mentioned above, which are extremely important for participation in the labour market and for citizenship and inclusion, more broadly.

Fix the leaky (STEM) pipeline!

Women find it hard to enrol and remain in STEM studies and exhibit higher drop-out rates or likelihood to switch majors than their male colleagues. Importantly, such patterns are unrelated to poor academic performance. This low study persistence and overall low graduation rates of women in STEM, also known as the "leaky pipeline", needs to be fixed by means of putting in place a number of concerted actions aimed at addressing the numerous factors determining it.

A mix made of: greater presence of female role models; education helping girls feeling more at ease with competition and peer-pressure; addressing self-censorship; teachers and professors ensuring gender-neutral approaches throughout STEM careers; and making students aware of STEM-related stereotypes in parental expectations can go a long way.

It would be helpful that education curricula and teacher training would note existing gender differences in STEM and the economic impact that they may have in the context of the Fourth Industrial Revolution; and how this may affect women's labour force participation and their employment opportunities and career prospects.

There are many examples of APEC economies moving in the right direction. For example, the NinaSTEMpueden initiative in Mexico highlights how education systems can become key actors for change and influence stereotypes through role modelling and career orientation for school-aged girls. The NinaSTEMpueden initiative illustrates that given the will to fight for equality between men and women as well as girls and boys, much is possible with little financial resources.

Design and shape lifelong learning opportunities, also for occupational transitions

The analysis on occupational transition indicates that while in the case of men it may be slightly easier to identify possible occupational transitions, women are more likely to find acceptable occupational transitions. This slightly higher proportion of acceptable transitions for women is, so to speak, the bright side of a medal, whose negative side is represented by the relatively lower wages generally earned by women (as compared to men). Mobility away from occupations at high risk of automation mostly requires acquiring self-organisation and management and communication skills, no matter the gender of the worker. The same is true for female workers in the full set of occupations.

Education and training system aimed at fostering the entry into the labour market and the occupational mobility of women should provide women with these sets of skills, and offer lifelong learning opportunities, allowing them to participate and thrive in constantly evolving labour markets.

Empower educators

Make teachers aware of gender biases and of their being role models for students

Teachers and professors can play an important twofold role in (female) students' career decisions and can act as powerful role models for their students. It is thus fundamental that teachers become aware of whether and to what extent their teaching style might reflect underlying gender-biased stereotypes, and address this, if necessary.

The stereotype of mathematics, physical sciences and technology as fields in which males exceed and where females lack talent is pervasive and may influence girls' confidence in their skills from a young age. By shaping the confidence that girls and boys have in their own abilities, stereotypes may reduce the willingness of girls to engage in fields that are perceived to be masculine and apply for occupations or jobs in sectors that are stereotypically masculine.

Students reporting that their teachers are willing to help and care about their learning are 1.3 times more likely to feel that they belong to school. Teachers would need to know how to help students understand their strengths and weaknesses, and help them address the latter, as otherwise students may tend to internalise mistakes as meaning that they are not smart enough, which is something that girls do disproportionally.

Interesting initiatives from APEC economies show that it is possible to build comprehensive approaches even in very difficult circumstances. For example, in Viet Nam, with European Union support, the Flemish Association for Development Cooperation and Technical Assistance, the Viet Nam Ministry of Education and Training, provincial and district education and training departments and a local NGO, the Research Centre for Gender, Family and Environment in Development, began implementing a gender-responsive play-based learning project in 2018. The project was implemented in 15 mountainous districts with high poverty, food insecurity, environmental threat and child marriage rates (i.e. the share of individuals getting married before reaching age 18). It focuses on kindergarten teachers, since the early years set the foundation for future learning and are a period of flexibility in brain development, when gender norms and stereotypes can be effectively challenged. When kindergarten teachers apply traditional gender values in the classroom, both teacher and student behaviours reflect gender stereotypes. Working with teachers, school leaders, parents and guardians, the project is transforming one pre-school per district into a model school that develops self-confidence, self-esteem and collaborative skills of 3- to 5-year-olds. The aim is to build gender-responsiveness among teachers, school leaders and government officials involved in supporting the economy's 156 pre-schools in 15 districts. To that end, the project has piloted a pre-school gender responsive play-based learning toolkit, and is working to strengthen capacity among pre-school teachers, school principals and government personnel. A parent-school sensitisation model is under way, with a particular focus on fathers. Finally, a planned nationwide advocacy campaign will embed the approach into the in-service pre-school teacher training curriculum (UNESCO, 2019).

Teachers as active agents for change

It is important that teachers become active agents for change and engage in innovation, and move away from considering their workplace as an essentially hostile-to-innovation environment. It is fundamental for education to help all individuals, and girls in particular, to take advantage of new tools and technologies while addressing concerns about misuse, abuse or any other possible drawback that digital technologies may entail. Those in charge of educating today's "connected" learners are confronted with a number of new (or newly relevant) issues. These encompass "information overload"; plagiarism; protecting children from online risks, including fraud, violations of privacy and online bullying, which disproportionally affect girls and women as victims; and setting an adequate and appropriate media diet.

Current and future teachers together with school leaders would need to be supported to ensure that they effectively integrate ICT and digital content in their schools. They would further need to be and remain competent users of ICT and digital technologies themselves.

The success of using ICTs for educational purposes relies heavily on teachers' abilities to select, create and manage adequate digital resources in order to implement innovative and inclusive teaching strategies in a specific context. Integrating digital literacy in teacher training may further encourage teachers to modify their approaches to teaching itself and help them reduce their adoption of stereotypical attitudes and transmit them to their students.

Make sure educational material and educational approaches are gender neutral

It is fundamental to rely on and develop inclusive educational approaches and educational material, which helps dismantling stereotypes and socio-cultural biases, both explicit and implicit ones. Whether for use on or off-line, and independently of the support (printed, digital or else), educational material and practices represent powerful tools in the quest for inclusion. For instance, having computer workers represented as women and images of men taking care of house chores - instead of representing families where "mummy cleans while daddy works on a computer in an office" - could help convey a sense of gender equality into the minds of students, and help make of gender equality the "new normal".

More generally, education should tackle implicit and explicit gender stereotypes, also by addressing and removing possible gender-biased content and pedagogical approaches.

Although relatively few interventions have been targeted at supporting curricular and textbook reforms, there are important initiatives that can be used to model change (UNESCO, 2019). One such initiative is the Gender Equality and Girls' Education Initiative in Viet Nam project (2015–2017) which, with support from the UNESCO Malala Fund for Girls' Right to Education, included a component on gender mainstreaming in curriculum and textbook development and teaching practices. In addition to contributing to the development of the Action Plan on Gender Equality of the Education Sector for 2016–2020, the project aimed to influence attitudes to gender mainstreaming in curriculum and textbook development through substantive capacity development. This was done targeting curriculum developers, trainers, managers, education practitioners and students at all levels, nationwide. Among the key results: The Ministry of Education and Training has developed a revised curriculum framework for primary and secondary education involving curriculum developers trained as part of the project. Revised curricula and textbooks will benefit over 15 million students and 850,000 teachers in Viet Nam (UNESCO, 2019).

Leadership is key to narrow divides and foster inclusions

It is important that both teachers and students are not "victims" of dysfunctional schools. To this end, a number of interrelated leadership responsibilities are key. These include: the need for school leaders to support, evaluate and develop teacher quality; establishing learning objectives and assessment designed to help students achieve high standards; using resources in a strategic fashion and having pedagogical approaches align with the objectives set; and fostering cohesion among all agents shaping the achievement and well-being of children, inside and outside schools.

Education and the school system should also make sure to convey the idea that leadership is not a male characteristic, and help dismantling the general implicit belief that holds tough men to be real leaders and tough women to be bossy, assertive and aggressive.

Mind the gap: plan to align expectations with reality and engage stakeholders throughout

Schools and education systems are, on average, not yet ready to leverage the potential of technology. Gaps in the digital skills of both teachers and students, difficulties in locating high-quality digital learning resources from among a plethora of poor-quality ones, a lack of clarity on the learning goals, and insufficient pedagogical preparation for blending technology meaningfully into lessons and curricula, create a wedge between expectations and reality. If these challenges are not addressed as part of the technology plans of schools and education ministries – and in the absence of gender lenses aimed at fostering inclusion and narrowing gender gaps - technology may do more harm than good to the teacher-student interactions that underpin deep conceptual understanding and higher-order thinking.

Motivation, empowerment, co-decision are among the incentive mechanisms that policy may try to leverage upon, together with better rewards and greater recognition.

Shape attitudes and expectations

Break the (vicious) circle: Lack of self-confidence and lack of relevant information go hand in hand

Girls are less confident in their math, science and IT abilities, at times due to or fuelled by societal and parental biases, and by parents' expectations about their future, independently of performance. Expectations about the future of work tend to be factored in more by men than by women while gender differences exist. Men systematically seek and benefit more from help and advice, think more than women about future work options when young, and are generally more aware about the need to retrain during their career.

Education may consider developing content and approaches aimed at tackling self-confidence, especially in the use of digital technologies. It can further help address gender biases in expectations by means of making all students, and girls in particular, aware of how different jobs and career options relate to different subjects. This would help girls make more informed decisions, which not only rely on what they are good at but also factor in future work possibilities.

Address self-censorship and help make girls aware of their real abilities

Girls seem to care more than boys that their efforts at school are properly recognised, but they are less likely than boys to report that they are ambitious or competitive in contexts that are not necessarily related to school. This discrepancy between the gender gap in actual performance and self-perceptions is particularly notable for more complex skills, such as locating specific information online or creating a multimedia presentation, and is in line with what observed in the case of science and mathematics.

Education can change this, by means of helping students improve their self-assessment competences and by enhancing the ability of students to align self-perception with performance.

School should engage with parents to shape expectations about the future

People tend to form beliefs about what they can achieve in life at a young age. The development of positive motivation to achieve at school is a prerequisite for success in life, particularly in high risk, high reward environments such as digital intensive sectors. In many economies, the gender gap in the expectations that students have for their future career, also STEM careers, reflects the gendered and stereotypical nature of parental expectations. The parents of boys are considerably more likely to expect that their children will work in a STEM occupation than the parents of girls, even when comparing boys and girls of similar levels of academic achievement.

Schools should educate students as critical consumers of Internet services and electronic media, helping them to make informed choices and avoid harmful behaviours. They can also raise awareness in families about the risks that children face online and how to avoid them. In addition to protecting children from online threats, parents should help children to balance leisure uses of ICT with time for other recreational activities that do not involve screens, such as sports and, equally important, sleep.

School should further engage with parents to shape expectations about the future and motivate students – and girls in particular – to achieve.

Stop discrimination and violence

Close the gender wage gap and address age-based discrimination

The gender wage gap characterises all parts of the economy, with differences emerging between digital-intensive and less digital-intensive industries. It can only partially be explained by differences in skill endowment and evidence shows that women tend to be less rewarded than men for the very same skills and that age penalises women but not men. In APEC economies, having kids and working in a digital intensive industry may lead women to earn 11% less, on average, than their male counterparts. In addition, age leads to lower returns to skills in all industries in the APEC economies considered.

Policy needs addressing the gender wage gap and ensure that female workers are not discriminated on the basis of age or motherhood. Education, including vocational one, may help upskilling or reskilling women after unemployment spells related to taking care of family or children.

Address time poverty and provide childcare and family support

Time poverty results, among others, out of unpaid work as household work and care for children and the elderly. This translates into lack of enough time for paid work, studies, rest and leisure. Overcoming time poverty calls for the provision of affordable services, even of basic ones such as water supply, electricity and access to sanitation, as well as childcare facilities and family support.

Policy should facilitate access to and participation in the education system of girls and women who have family or children responsibilities. Digital technologies may help in this respect, as they may enhance learning opportunities and flexibility and allow for distance learning. However, participating in digitally-enabled distance learning requires having a basic set of IT skills, which education needs endowing all students with to begin with.

Stop online violence!

Online harassment remains one of the key constraints for the full uptake of ICT. Adolescents' use of ICT is a source of concern among parents, teachers and policy makers and safety-related concerns often lead families to oppose the use of the Internet or the ownership of a mobile phone. Women, especially at a younger age, as well as sexual and gender minorities, are more likely to become victims of gender-based violence, in all economies. Compared to their male peers, girls are more often the object of personal attacks and cyber bulling on social networks. Non-consensual pornography - a relatively new phenomenon - also affects predominantly, but not exclusively, female undergraduate students.

Policy makers should put in place a number of policies aimed at making all actors involved, including Internet and content users and providers, responsible and accountable for their online presence and actions.

Also, education could formulate clear guidelines on the responsible use of the Internet and online behaviours, which could become part of civics' or ethics' curricula. Discussing potential benefits and risks of online presence, as well as privacy and security issues - including cyberbullying – at school would not only help raise awareness, but also help build resilience when facing online violence.

The need for a systemic approach to bridge the digital gender divide

Innovate, include, engage, act and monitor in a timely fashion

For curricula to better meet the needs and desiderata of everyday life, society and work, and in order to make of education the place where gender biases end, it is important to involve different stakeholders in the design of education and learning systems, including educators, companies, and families. Also, international evidence shows that implementing curriculum reforms successfully require targeting complementary policy areas, such as assessment practices and support and training for teachers, among others.

Policies fostering educational innovation and performance need encompassing actions aimed at reducing disparities and actively supporting inclusion, especially gender-related. It is important to reduce disparities between the most and least advantaged schools (e.g. in poor neighbourhoods, rural areas) and to distribute resources across schools, as equity can be undermined when students and schools are matched based on socioeconomic background. Socio-economic status and gender often interact to shape individuals' learning trajectories.

It is also important to act in a timely manner, as at present, the gap between curriculum intent and learning outcomes appears generally too wide and by the time reforms are implemented they may already be obsolete and unable to address the very challenges they are supposed to deal with.

Last but not least, it is key to embed programme assessment in the design of education policies, to be able to constantly monitor progress and hurdles, and to adjust design and re-tailor efforts where and when needed.

References

A4AI (2018), *2018 Affordability Report*, Alliance for Affordable Internet, 2018, https://a4ai.org/affordability-report/report/2018/ (accessed on 8 June 2019).Abernathy, W. and K. Clark (1985), "Innovation: Mapping the winds of creative destruction", *Research Policy*, Vol. 14 (1), pp. 3-22, https://doi.org/10.1016/0048-7333(85)90021-6.

ADB (2015), *Balancing the Burden, Desk review of women's time poverty and infrastructure in Asia and the Pacific*, Manila, Philippines: Asian Development Bank Publishing, https://www.adb.org/sites/default/files/publication/177465/sdcc-balancing-burden.pdf.

Amnesty (2019), "Toxic Twitter – Women's Experiences of Violence and Abuse on Twitter", webpage, https://www.amnesty.org/en/latest/research/2018/03/online-violence-against-women-chapter-3/#topanchor (accessed on 8 June 2019).

Amnesty (2017), "Unsocial Media: The Real Toll of Online Abuse against Women", webpage, https://medium.com/amnesty-insights/unsocial-media-the-real-toll-of-online-abuse-against-women-37134ddab3f4 (accessed on 24 July 2019).

Andrieu, E., S. Jamet, L. Marcolin, L. and M. Squicciarini (2019), "Occupational transitions: The cost of moving to a "safe haven"", *OECD Science, Technology and Industry Policy Papers*, No. 61, OECD Publishing, Paris, https://doi.org/10.1787/6d3f9bff-en.

Antonio, A. and D. Tuffey (2014), "The gender digital divide in developing countries", *Future Internet*, Vol. 6/4, pp. 673-687, https://doi.org/10.3390/fi6040673.

APEC (2018), "Public and Private Sectors' Strategies to Prevent Gender-based Violence, Reduce Costs and Develop Capacity in APEC Economies", *APEC Policy Partnership on Policy and the Economy*, https://www.apec.org/Publications/2018/04/Public-and-Private-Sectors-Strategies-to-Prevent-Gender-based-Violence (accessed on 5 July).

Ashcraft, C., B. McLain and E. Eger (2016), *Women in Tech: The Facts, National Center for Women & Technology* (NCWIT)https://www.ncwit.org/resources/women-tech-facts-2016-update (accessed on 3 June 2019).

Astorne-Figari, C. and J. Speer (2018), "Drop out, switch majors, or persist? The contrasting gender gaps", *Economics Letters*, Vol. 164, pp. 82-85, https://doi.org.10.1016/j.econlet.2018.01.010.

Autor, D., Levy, F. and R. Murnane (2003), "The Skill Content Of Recent Technological Change: An Empirical Exploration", *Quarterly Journal of Economics, Vol.* 118, https://doi.org/10.1162/003355303322552801 .

Backe, E., P. Lilleston and J. McCleary-Sills (2018), "Networked Individuals, Gendered Violence: A Literature Review of Cyberviolence", *Violence and Gender*, Vol. 5 (3), http://doi.org/10.1089/vio.2017.0056.

Barone, C. (2011), "Some things never change", *Sociology of Education*, Vol. 84/2, pp. 157-176, http://dx.doi.org/10.1177/ 0038040711402099.

Baxter, J., B. Hewitt and M. Haynes (2008), "Life Course transitions and housework: Marriage, parenthood, and time on housework", *Journal of Marriage and Family*, Vol. 70 (2), pp. 259-272, https://doi.org/10.1111/j.1741-3737.2008.00479.x .

Bechichi, N. et al. (2019), "Occupational mobility, skills and training needs", *OECD Science, Technology and Industry Policy Papers*, No 70, OECD Publishing, Paris, https://doi.org/10.1787/30a12738-en.

Beilock, S., et al. (2010), Female teachers' math anxiety affects girls' math achievement", *Proceedings of the National Academy of Sciences*, Vol. 107(5), pp. 1860–1863, https://doi.org/10.1073/pnas.0910967107.

Benavot, A. and C. Jere 2016), "Gender bias is rife in textbooks", UNESCO Global Education Monitoring Report Blog, https://gemreportunesco.wordpress.com/2016/03/08/gender-bias-is-rife-in-textbooks/ (accessed on 24 August 2019).

Berki, E. and F. Cobb-Payton (2005), "Work-Life Balance and Identity in a Virtual World: Facts, Tensions and Intentions for Women in IT*"* in H. Isomäki and A. Pohjola (ed.): *Lost and Found in Virtual Reality: Women and Information Technology*, p. 275–96, Rovaniemi: University of Lapland Press.

Bertrand, M., M. Mogstad and J. Mountjoy (2019), "Improving Educational Pathways to Social Mobility: Evidence from Norway's "Reform 94"", National Bureau of Economic Research, Working Paper, No. 25679, https://doi.org/10.3386/w25679 .

Black, S.E. and A. Spitz-Oener (2010), "Explaining women's success: Technological change and the skill content of women's work", *The Review of Economics and Statistics*, Vol. 92(1), pp. 187-194, https://doi.org/10.3386/w13116.

Borgonovi, F. (2016), "Video Gaming and gender differences in digital and printed reading performance among 15-year-olds students in 26 countries", *Journal of Adolescence*, Vol. 48 (April), pp. 45-61, https://doi.org/10.1016/j.adolescence.2016.01.004.

Branch et al. (2017), "Revenge porn victimization of college students in the United States: An exploratory analysis", *International Journal of Cyber Criminology*, Vol. 11 (1), pp. 128-142, https://doi.org/10.5281/zenodo.495777.

Broadband Commission (2015), *Cyber Violence Gender Report*, UN Broadband Commission, http://www.unwomen.org/~/media/headquarters/attachments/sections/library/publications/2015/cyber_violence_gender%20report.pdf?v=1&d=20150924T154259 (accessed on 8 June 2019).

Burston, M. (2017), "I work and don't have time for that theory stuff: time poverty and higher education", *Journal of Further and Higher Education*, Vol. 41(4), pp.516-529, https://doi.org/10.1080/0309877X.2015.1135885.

Cain, N. and M. Gradisar (2010), "Electronic media use and sleep in school-aged children and adolescents: A review", Sleep Medicine, Vol. 11/8, 735-742, https://doi.org/10.1016/j.sleep.2010.02.006.

Campuzano, L. et al. (2009), "Effectiveness of Reading and Mathematics Software Products", U.S. Department of Education, Institute of Education Sciences, https://ies.ed.gov/ncee/pubs/20094041/pdf/20094042.pdf.

Carlana, M. (2018), "Stereotypes and Self-Stereotypes: Evidence from Teachers' Gender Bias", IZA Discussion Paper No. 11659 , http://ftp.iza.org/dp11659.pdf

Carrell, S. E., Page, M. E., and West, J. E. (2010), "Sex and science: How professor gender perpetuate the gender gap", *The Quarterly Journal of Economics*, Vol. 125(3), pp. 1101-1144, https://doi.org/10.3386/w14959.

Cecil, A. L. (2014), "Taking back the internet: Imposing civil liability on interactive computer services in an attempt to provide an adequate remedy to victims of non-consensual pornography", *Washington* *and Lee Law Review*, Vol. 71, pp. 2513-2556, https://heinonline.org/HOL/LandingPage?handle=hein.journals/waslee71&div=63&id=&page=&t=1560015132.

Citron, D. and M. Franks (2014), "Criminalizing revenge porn", *Wake Forest Law Review*, Vol. 49, pp. 345-391, https://heinonline.org/HOL/LandingPage?handle=hein.journals/wflr49&div=15&id=&page=&t=1560015128 (accessed 9 June 2019).

COE (2018), *Mapping study on cyberviolence*, Council of Europe, Cybercrime Convention Committee (T-CY) Working Group on cyberbullying and other forms of online violence, especially against women and children, T-CY(2017)10, https://rm.coe.int/t-cy-2017-10-cbg-study-provisional/16808c4914 (accessed on 9 June).

Cooper, J. (2006), "The digital divide: the special case of gender", *Journal of Computer Assisted Learning*, Vol. 22, p. 320-334, https://doi.org/10.1111/j.1365-2729.2006.00185.x.

Council on Communications and Media (2013), "Children, adolescents, and the media", Pediatrics, Vol. 132, pp. 958-961, www.pediatrics.org/cgi/doi/10.1542/peds.2013-2656.

Covington, M.V. and K. J. Müller (2001), "Intrinsic versus extrinsic motivation: An approach/avoidance reformulation", *Educational Psychology Review*, Vol. 13/2, pp. 157-176, https://doi.org/10.1023/A:1009009219144.

Damon, W., J. Menon and K.C. Bronk (2003), "The development of purpose during adolescence", *Journal of Applied Developmental Science*, Vol. 7/3, pp. 119-128, https://web.stanford.edu/group/adolescence/cgi-bin/coa/sites/default/files/devofpurpose_0.pdf.

Dasgupta, N. and J. Stout (2014), "Girls and Women in Science, Technology, Engineering, and Mathematics: STEMing the Tide and Broadening Participation in STEM Careers", *Policy Insights from the Behavioral and Brain Sciences*, Vol. 1(1), pp. 21–29, https://doi.org/10.1177/2372732214549471.

Davis, S. et al. (2006), "Volatility and Dispersion in Business Growth Rates: Publicly Traded versus Privately Held Firms [with Comments and Discussion]," *NBER Macroeconomics Annual,* Vol. 21,pp. 107-179, https://doi.org/10.1086/ma.21.25554954 .

Davy, J et al. (2019), "Analyses of Time Use in Informal Economy Workers Reveals Long Work Hours, Inadequate Rest and Time Poverty", *Proceedings of the 20th Congress of the International Ergonomics Association* (IEA 2018), Volume II: Safety and Health, Slips, Trips and Falls, pp. 415-424, https://doi.org/10.1007/978-3-319-96089-0_45.

Duckworth, A.L. et al. (2011), "Self-regulation strategies improve self-discipline in adolescents: Benefits of mental contrasting and implementation intentions", *Educational Psychology*, Vol. 31/1, pp. 17-26, https://doi.org/10.1080/01443410.2010.506003.

Eccles, J.S. and A. Wigfield (2002), "Motivational beliefs, values, and goals", *Annual Review of Psychology*, Vol.53, pp. 109-132, https://doi.org/10.1146/annurev.psych.53.100901.135153.

EU COM (2015), *She Figures 2015. Gender in Research and Innovation. Statistics and Indicators*; European Commission Directorate-General for Research and Innovation, Brussels, Belgium, https://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015-final.pdf (accessed on 3 June 2019).

Fallows, D. (2005), "How Women and Men Use the Internet", Pew Internet and American Life Project, webpage, www.pewinternet.org/2005/12/28/how-women-and-men-use-the-internet/ (accessed 3 June 2019).

Favaretto, M., E. De Clercq and B. Elger (2019), "Big Data and discrimination: perils, promises and solutions. A systematic review", *Journal of Big Data*, Vol. 6 (1), https://doi.org/10.1186/s40537-019-0177-4 .

Felstead, A., D. Gallie, F. Green and H. Inanc (2013), "Work intensification in Britain: first findings from the Skills and Employment Survey 2012", London: Centre for Learning and Life Chances in Knowledge Economies and Societies, Institute of Education, http://orca.cf.ac.uk/67987/1/5.%20Work%20Intensification%20in%20Britain%20-%20mini-report.pdf.

Finn, S. and M. Gorr (1988), "Social isolation and social support as correlates of television viewing motivations", *Communication Research*, Vol. 15/2, pp. 135-158, https://doi.org/doi.org/10.1177/009365088015002002.

Fischer, S. (2017), "The downside of good peers: How classroom composition differentially affects men's and women's STEM persistence", *Labour Economics*, 46, pp. 211-226, https://doi.org/10.1016/j.labeco.2017.02.003.

FRA (2014), *Violence against women: an EU-wide survey*, European Union Agency for Fundamental Rights, https://fra.europa.eu/sites/default/files/fra_uploads/fra-2014-vaw-survey-main-results-apr14_en.pdf.

Fraillon, J. et al. (2015), "National Assessment Program: ICT Literacy Years 6 & 10 Report 2014", https://research.acer.edu.au/ict_literacy/11.

Fraillon, J., W. Schulz and J. Ainley (2013), "International Computer and Information Literacy Study Assessment Framework", webpage, http://www.iea.nl (accessed 23 July).

Frey, C. and M. Osborne (2017), "The Future of Employment", *Working Paper published by the Oxford Martin Programme on Technology and Employment*, https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf.

Gick, M. (1986), "Problem-Solving Strategies", *Educational Psychologist*, Vol. 21(1-2), pp.99-120, https://doi.org/10.1080/00461520.1986.9653026.

Goldin, C. (2014), "A grand gender convergence: Its last chapter", *American Economic Review*, 104(4), 1091-1119, http://dx.doi.org/10.1257/aer.104.4.1091.

Gray, T., J. Gainous and K. Wagner (2017), "Gender and the Digital Divide in Latin America", *Social Science Quarterly*, Vol. 98 (1), pp. 326-340, https://doi.org/10.1111/ssqu.12270 .

Greeno, J. (1978), "Natures of problem-solving abilities" in W. K. Estes (Eds): *Handbook of learning & cognitive processes: V. Human information*, pp. 239-270, Oxford, England: Lawrence Erlbaum. https://psycnet.apa.org/record/1978-19902-005.

Greiff, S., Wüstenberg, S., and Avvisati, F. (2015), "Computer-generated log-file analyses as a window into students' minds? A showcase study based on the PISA 2012 assessment of problem solving", *Computers & Education*, 91(C), 92-105, https://doi.org/10.1016/j.compedu.2015.10.018 .

Grundke, R., Marcolin, L., Nguyen, T. L. B. and M. Squicciarini (2018), "Which skills for the digital era?: Returns to skills analysis", *OECD Science, Technology and Industry Working Papers*, No. 2018/09, OECD Publishing, Paris, https://doi.org/10.1787/9a9479b5-en.

Grundke, R., Jamet S., Kalamova M., Keslair F. and M Squicciarini (2017), "Skills and global value chains: A characterisation", OECD Science, Technology and Industry Working Papers, No. 2017/05, OECD Publishing, Paris, https://doi.org/10.1787/cdb5de9b-en.

Grunow, D., F. Schulz and H.-P. Blossfeld (2012), "What determines change in the division of housework over the course of marriage?", *International Sociology*, Vol. 27 (3), pp. 289-307, https://doi.org/10.1177/0268580911423056 .

GSMA (2019), *The Mobile Economy Report 2019*, GSMA, 2019, https://www.gsmaintelligence.com/research/?file=b9a6e6202ee1d5f787cfebb95d3639c5&download (accessed 3 June 2019).

GSMA (2018), *Connected Women – The Mobile Gender Gap Report 2018*, https://www.gsma.com/mobilefordevelopment/wpcontent/uploads/2018/03/GSMA_The_Mobile_Gender_Gap_Report_2018_Final_210218.pdf (accessed 3 June 2019).

GSMA (2015), *Connect Women 2015 - Bridging the gender gap: Mobile access and usage in low- and middle-income countries*, http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2016/02/Connected-Women-Gender-Gap.pdf .

Gupta, S. (1999), "The effects of transitions in marital status on men's performance of housework", *Journal of Marriage and Family*, Vol. 61 (3), pp. 700-711, https://doi.org/10.2307/353571 .

Hao, K. (2019), "Facebook's ad-serving algorithm discriminates by gender and race", MIT Technology Review's AI newsletter "*The Algorithm*", 5 April 2019, https://www.technologyreview.com/s/613274/facebook-algorithm-discriminates-ai-bias/ (accessed on 24 August 2019),

Harding, S. (1986), *The Science Question in Feminism*, New York: Cornell University Press.

Hanushek, E.A., Piopiunik, M., and S. Wiederhold (2019), "The Value of Smarter Teachers: International Evidence on Teacher Cognitive Skills and Student Performance", *J. Human Resources*, https://doi.org/10.3368/jhr.55.1.0317.8619R1.

He, Q., Borgonovi F. and M. Paccagnella (2019), "Using Process Data to Understand Adults' Problem-Solving Behaviour in the Programme for the International Assessment of Adult Competencies (PIAAC): Identifying Generalised Patterns across Multiple Tasks with Sequence Mining", *OECD Education Working Paper No. 205*, OECD Paris, https://dx.doi.org/10.1787/650918f2-en.

He, Q., and von Davier, M. (2016), "Analyzing Process Data from Problem-Solving Items with N-Grams: Insights from a Computer-Based Large-Scale Assessment." *Handbook of research on technology tools for real-world skill development*. IGI Global, pp. 750-777, https://doi.org/10.4018/978-1-4666-9441-5.ch029.

He, Q., and Von Davier, M. (2015), "Identifying Feature Sequences from Process Data in Problem-Solving Items with N-Grams", In L. van der Ark et al. (Eds.), *Quantitative Psychology Research The 79th Annual Meeting of the Psychometric Society* (pp. 173-190), Springer, New York, NY, https://doi.org/10.1007/978-3-319-19977-1_13.

Henry, N. and A. Powell (2018), "Technology-Facilitated Sexual Violence: A Literature Review of Empirical Research", *Trauma, Violence, and Abuse*, Vol. 19 (2), pp. 195-208, https://doi.org/10.1177/1524838016650189.

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

Hook, J. (2017), "Women's Housework: New Tests of Time and Money*", Journal of Marriage and Family*, Vol. 79 (1), pp. 179-198, https://doi.org/10.1111/jomf.12351.

House of Commons Health Committee (2014), HC 342 - *Children's And Adolescents' Mental Health and CAMHS*, The Stationery Office.

Howcroft, D. and J. Rubery (2019): "Bias in, Bias out': gender equality and the future of work debate", *Labour & Industry: a journal of the social and economic relations of work*, https://doi.org/10.1080/10301763.2019.1619986 .

Husu, L. (2001), "Sexism, Support and Survival in Academia", in: *Academic Women and Hidden Discrimination in Finland*, Helsinki: University of Helsinki, https://www.researchgate.net/publication/274192317_Sexism_support_and_survival_in_academia_the_Finnish_experience.

Hysing, M. et al. (2015), "Sleep and use of electronic devices in adolescence: results from a large population-based study", BMJ Open, Vol. 5/1, http://dx.doi.org/10.1136/bmjopen-2014-006748.

ILO (2018), *Care work and care jobs for the future of decent work*, https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_633135.pdf (accessed in 24 August 2019).

Intel and Dalberg (2012), *Women and the Web. Bridging the Internet and Creating New Global Opportunities in Low and Middle Income Countries*, Intel Corporation and Dalberg Global Development Advisors, https://www.intel.com/content/dam/www/public/us/en/documents/pdf/women-and-theweb.pdf .

Isaca (2017), *The Future Tech Workforce: Breaking the Gender Barriers*, webpage, http://www.isaca.org/info/2017-women-in-technology-survey/index.html (accessed on 3 June 2019).

Isphording, I. and P. Qendrai (2019), Gender Differences in Student Dropout in STEM, Institute for Labour Economics (IZA), IZA Research Report No. 87, http://ftp.iza.org/report_pdfs/iza_report_87.pdf.

ITU (2019), "Gender ICT Statistics", World Telecommunication/ICT Indicators (database), https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx (downloaded on 29 May 2019).

ITU (2018), World Telecommunication/ICT Indicators (database), https://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2018/Individuals%20using%20the%20Internet%20by%20gender%20-%20Jan2018.xls .

ITU (2017), *ICT Facts and Figures 2017*, http://www.itu.int/en/ITUD/Statistics/Documents/facts/ICTFactsFigures2017.pdf .

ITU (2014), Measuring the Information Society Report, International Telecommunication Union, Geneva.

Ji, P. and M. Skoric (2013), "Gender and social resources: Digital divides of social network sites and mobile phone use in Singapore", *Chinese Journal of Communication*, 6 (2), pp. 221-239, https://doi.org/10.1080/17544750.2013.785673.

Johnson J.G. et al. (2007), "Extensive television viewing and the development of attention and learning difficulties during adolescence", *Archives of Pediatrics & Adolescent Medicine*, Vol. 161/5, pp. 480-486, http://dx.doi.org/10.1001/archpedi.161.5.480.

Jonassen, D (1997), "Instructional design models for well-structured and III-structured problem-solving learning outcomes", *Educational Technology Research and Development*, Vol. 45 (1), pp 65–94, https://doi.org/10.1007/BF02299613.

Karam, R. et al. (2016), "Examining the implementation of technology-based blended algebra I curriculum at scale", *Educational Technology Research and Development*, Vol. 65/2, pp. 399-425, http://dx.doi.org/10.1007/s11423-016-9498-6.

Kim, K. et al. (2006), "Internet addiction in Korean adolescents and its relation to depression and suicidal ideation: A questionnaire survey", *International Journal of Nursing Studies*, Vol. 43/2, pp. 185-192, https://doi.org/10.1016/j.ijnurstu.2005.02.005.

Kruger, D. I., Berthelon, M. and R. Navia (2009). "Adolescent Motherhood and Secondary Schooling in Chile". Institute for the Study of Labor, IZA Discussion Paper, n. 4552, Bonn, Germany, http://ftp.iza.org/dp4552.pdf

Kugler, A. and Tinsley, C. and Ukhaneva, O. (2017), "Choice of Majors: Are women really different from men?", *National Bureau of Economic Research*, No. w23735, https://doi.org/10.3386/w23735.

Kuosa, T. (2000), "Masculine World Disguised as Gender Neutral", in E. Balka and R. Smith (ed.): *Women, Work and Computerization*, p. 119–26, Boston, MA: Kluwer Academic.

Lamolla, L. and A. González Ramos (2018), "Tick-tock sounds different for women working in IT areas", *Community Work Fam.*, pp. 1–16, https://doi.org/10.1080/13668803.2018.1483321.

Latimer, C. P. (2001), *The digital divide: Understanding and addressing the challenge*, New York, NY: New York State Forum for Information Resource Management.

Laxton, C. (2014), *Virtual world, real fear- Women's Aid report into online abuse, harassment and stalking*, Womensaid, webpage, https://1q7dqy2unor827bqjls0c4rn-wpengine.netdna-ssl.com/wp-content/uploads/2015/11/Women_s_Aid_Virtual_World_Real_Fear_Feb_2014-3.pdf (accessed on 8 June 2019).

Lee, J. and P. Collins (2010), "Construction of gender: a comparison of Australian and Hong Kong English language textbooks", Journal of Gender Studies, Vol. 19, No 2, pp. 121-137, https://doi.org/10.1080/09589231003695856 .

Lepper, M.R., J.H. Corpus and S.S. Iyengar (2005), "Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates", *Journal of Educational Psychology*, Vol. 97/2, pp. 184-196, https://doi.org/10.1037/0022-0663.97.2.184.

Lie, M. (1995), "Technology and Masculinity: The Case of the Computer", *European Journal of Women's Studies*, Vol. 2 (3), pp. 379–94., https://doi.org/10.1177/135050689500200306.

Lyon, S., Mutersbaugh and H. Worthen (2017), "The triple burden: the impact of time poverty on women's participation in coffee producer organizational governance in Mexico", *Agriculture and Human Values*, Vol. 34 (2), pp. 317-331, https://doi.org/10.1007/s10460-016-9716-1.

Marcolin, L., Miroudot, S. and M. Squicciarini (2019), "To be (routine) or not to be (routine), that is the question: a cross-country task-based answer", *Industrial and Corporate Change*, Vol. 28 (3), pp. 477–501, https://doi.org/10.1093/icc/dty020.

Marganski, A. and L. Melander (2018), "Intimate Partner Violence Victimization in the Cyber and Real World: Examining the Extent of Cyber Aggression Experiences and Its Association with In-Person Dating

Violence", *Journal of Interpersonal Violence*, Vol. 33 (7), pp. 1071-1095, https://doi.org/10.1177/0886260515614283.

Mason, M.A., Younger, J. (2014), "Title IX and Pregnancy Discrimination in Higher Education: The New Frontier", Review of law and social change, *New York University*, 38 (2), pp. 209-245, https://scholarship.law.berkeley.edu/facpubs/2470/.

McNeal, R., S. Kunkle and M. Schmeida (2018), *Cyber harassment and policy reform in the digital age: Emerging research and opportunities*, pp. 1-170.

Melkevik, O., T. Torsheim, R.J. Iannotti and B. Wold (2010), "Is spending time in screen-based sedentary behaviors associated with less physical activity: A cross national investigation", *International Journal of Behavioral Nutrition and Physical Activity*, Vol. 7/46, https://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-7-46.

Niederle, M., Vesterlund, L. (2007), "Do Women Shy Away From Competition? Do Men Compete Too Much?", *The Quarterly Journal of Economics*, Volume 122 (3), pp. 1067– 1101, https://doi.org/10.1162/qjec.122.3.1067.

OECD (2019a), *Trends Shaping Education 2019*, OECD Publishing, Paris, https://doi.org/10.1787/trends_edu-2019-en.

OECD (2019b), *Eurostat-OECD definition of ICT specialists*, OECD Publishing, Paris, http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/ICCP/IIS(2015)7/FINAL&docLanguage=En.

OECD (2019c), "A measurement roadmap for the future", in Measuring the Digital Transformation: A Roadmap for the Future, OECD Publishing, Paris, https://www.oecd.org/publications/measuring-the-digital-transformation-9789264311992-en.htm.

OECD (2019d), ICT Access and Usage by Households and Individuals (database), https://stats.oecd.org/Index.aspx?DataSetCode=ICT_HH2 (accessed on 3 July 2019).

OECD (2018a), *Education at a Glance 2018: OECD Indicators*, OECD Publishing, Paris. http://dx.doi.org/10.1787/eag-2018-en.

OECD (2018b), *Bridging the Digital Gender Divide – Include, Upskill, Innovate,* http://www.oecd.org/internet/bridging-the-digital-gender-divide.pdf.

OECD (2018c), *Financial Markets, Insurance and Private Pensions: Digitalisation and Finance,* http://www.oecd.org/finance/Financial-markets-insurance-pensions-digitalisation-and-finance.pdf.

OECD (2017a), *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264268821-en.

OECD (2017b), *PISA 2015 Results (Volume III): Students' Well-Being, PISA*, OECD Publishing, Paris, https://doi.org/10.1787/9789264273856-en.

OECD (2017c), *The Next Production Revolution: Implications for Governments and Business*, OECD Publishing, Paris, https://doi.org/10.1787/9789264271036-3-en.

OECD (2017d). *The Pursuit of Gender Equality: an Uphill Battle*. OECD Publishing, Paris. https://doi.org/10.1787/9789264281318-en.

OECD (2016a), *Education at a Glance 2016: OECD Indicators,* OECD Publishing, Paris.

OECD (2016b), *PISA 2015 Results (Volume II): Policies and Practices for Successful Schools, PISA*, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264267510-en.

OECD (2016c), *Big Data: Bringing Competition Policy to the Digital Era*, http://www.oecd.org/daf/competition/big-data-bringing.

OECD (2015a), *Making open science a reality*, OECD Science, Technology and Industry Policy Papers, No. 25, OECD Publishing, Paris, http://dx.doi.org/10.1787/5jrs2f963zs1-en.

OECD (2015b), *OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society*, OECD Publishing, Paris. http://dx.doi.org/10.1787/sti_scoreboard-2015-en.

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

OECD (2015d), *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264229945-en.

OECD (2014), "Trends Shaping Education 2014 Spotlight 5: Infinite Connections", www.oecd.org/edu/ceri/Spotlight%205-%20Infinite%20Connections.pdf.

OECD (2013), *PISA 2012 Results: Ready to Learn (Volume III): Students' Engagement, Drive and Self-Beliefs*, OECD Publishing, Paris, https://doi.org/10.1787/9789264201170-en.

OECD (2012a), The Protection of Children Online, Recommendation of the OECD Council, OECD Publishing, Paris, www.oecd.org/sti/ieconomy/childrenonline_with_cover.pdf.

OECD (2012b), "Emerging issues for education", in OECD, Connected Minds: Technology and Today's Learners, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264111011-9-en.

OECD (2010), "The policy debate about technology in education", in OECD, Are the New Millennium Learners Making the Grade?: Technology Use and Educational Performance in PISA 2006, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264076044-4-en.

OECD (2001), "Understanding the Digital Divide", OECD Digital Economy Papers, No. 49, OECD Publishing, Paris, https://doi.org/10.1787/236405667766.

OECD (1999), "Indicator E6: Computers in schools and their use", in Education at a Glance 1998: OECD Indicators, OECD Publishing, Paris, http://dx.doi.org/10.1787/eag-1998-en.

Pashang, S., N. Khanlou, N. and J. Clarke (2018), "The Mental Health Impact of Cyber Sexual Violence on Youth Identity", *International Journal of Mental Health and Addiction*, Article in Press, https://doi.org/10.1007/s11469-018-0032-4.

Pepin, J., L. Sayer and L. Casper (2018), "Marital Status and Mothers' Time Use: Childcare, Housework, Leisure, and Sleep", *Demography*, Vol. 55 (1), pp. 107-133, https://doi.org/10.1007/s13524-018-0647-x

Pew Research Centre (2017), *Online Harassment 2017*, webpage, https://www.pewinternet.org/2017/07/11/online-harassment-2017/ (accessed on 8 June 2019).

Pew Research Centre (2014), *Online Harassment 2014*, webpage, https://www.pewinternet.org/2014/10/22/online-harassment/ (accessed on 8 June 2019).

Population Health Division (2015), "Australia's Physical Activity and Sedentary Behaviour Guidelines", Australian Government Department of Health, www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines#apa1317.

Qi, L. and X.-Y. Dong (2018), "Gender, Low-Paid Status, and Time Poverty in Urban China", *Feminist Economics*, Vol. 24 (2), pp. 171-193, https://doi.org/10.1080/13545701.2017.1404621.

Richards, R, R. McGee, S. Williams, D. Welch, Hancox R. (2010), "Adolescent Screen Time and Attachment to Parents and Peers", *Arch Pediatr Adolesc Med*, Vol. 164(3), pp. 258–262, https://doi.org/10.1001/archpediatrics.2009.280 .

Quesenberry, J. and E. Trauth (2012), "The (dis)Placement of Women in the IT Workforce: An Investigation of Individual Career Values and Organizational Interventions", *Information Systems Journal*, Vol. 22 (6), pp. 457-73, https://doi.org/10.1111/j.1365-2575.2012.00416.x.

Quesenberry, J., E. Trauth and J. Morgan (2006), "Understanding the "Mommy Tracks: A Framework for Analyzing Work–Family Balance in the IT Workforce", *Information Resources Management Journal*, Vol. 19 (2), pp. 37-53. https://www.academia.edu/4603537/Understanding_the_Mommy_Tracks_A_Framework_for_Analyzing_Work-Family_Issues_in_the_IT_Workforce (accessed 3 June 2019).

Redecker, C. (2017), *European Framework for the Digital Competence of Educators: DigCompEdu*, Punie, Y. (ed). EUR 28775 EN. Publications Office of the European Union, Luxembourg, ISBN 978-92-79-73494-6, https://doi.org/10.2760/159770, JRC107466.

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

Rosser, S. (2004), "The Science Glass Ceiling", 16.2.2004, Press Release, The Georgia Institute of Technology.

Sayer, L. (2016), "Trends in Women's and Men's Time Use, 1965 - 2012: Back to the Future?", in McHale et al. (ed.): *Gender and Couple Relations*, New York: Springer.

Sey, A. and Hafkin, N. (Eds). (2019). "*Taking stock: Data and evidence on gender equality in digital access, skills and leadership*", United Nations University Institute on Computing and Society/International Telecommunications Union: Macau.

Smith, P.K. et al. (2008), "Cyberbullying: Its nature and impact in secondary school pupils", *Journal of Child Psychology and Psychiatry*, Vol. 49/4, pp. 376-385, https://doi.org/10.1111/j.1469-7610.2007.01846.x.

Speer, J. D. (2017), "The gender gap in college major: Revisiting the role of pre-college factors", *Labour Economics*, Vol. 44, pp. 69-88, https://doi.org/10.1016/j.labeco.2016.12.004.

Stoet, G. and D. Geary (2018), "The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education", *Psychological Science*, Vol. 29(4), pp. 581–593, https://doi.org/10.1177/0956797617741719.

Sukkarieh, J., von Davier, M. and K. Yamamoto (2012), "From Biology to Education: Scoring and Clustering Multilingual Text Sequences and Other Sequential Tasks", *ETS Research Report Series*, 2012(2), i-43, https://doi.org/10.1002/j.2333-8504.2012.tb02307.x.

Sutter, M. and D. Glätzle-Rützler (2015), "Gender Differences in the Willingness to Compete Emerge Early in Life and Persist. Management Science", *INFORMS*, Vol. 61(10), pp. 2339-23354, October.

Tiainen, T. and E. Berki (2019), "The re-production process of gender bias: a case of ICT professors through recruitment in a gender-neutral country", *Studies in Higher Education*, Vol. 44(1), pp.170-184, https://doi.org/10.1080/03075079.2017.1351428.

Thompson, C. (2019) "The secret history of women in coding. Computer programming once had much better gender balance than it does today. What went wrong?", *The New York Time Magazine*, 13 February 2019, https://www.nytimes.com/2019/02/13/magazine/women-coding-computer-programming.html (accessed on 25 August 2019).

UN (2019): The State of the World's Children, https://www.unicef.org/sowc2013/statistics.html (accessed 3 June 2019).

UN (2017), The Sustainable Development Goals Report 2017. New York: United Nations Publishing, https://unstats.un.org/sdgs/files/report/2017/thesustainabledevelopmentgoalsreport2017.pdf.

UNESCO (2019), *Global Education Monitoring Report – Gender Report: Building bridges for gender equality,* Paris, UNESCO, https://unesdoc.unesco.org/ark:/48223/pf0000368753/PDF/368753eng.pdf.multi (accessed on 24 August 2019).

UNESCO (2018), "A Global Framework to Measure Digital Literacy", webpage, http://uis.unesco.org/en/blog/global-framework-measure-digital-literacy (accessed on 24 July 2019).

UNESCO (2007), Education for All Global Monitoring Report 2007, Strong Foundation Early childhood care and education, http://www.unesco.org/education/GMR/2007/Full_report.pdf .

UNFPA (2015), "Girlhood, Not Motherhood: Preventing Adolescent Pregnancy". New York, UNFPA. https://www.unfpa.org/sites/default/files/pub-pdf/Girlhood_not_motherhood_final_web.pdf

UNSD (United Nations Statistics Division) (2017), "SDG Indicators Global Database", https://unstats.un.org/sdgs/indicators/database/ (accessed on 20 August 2019).

UN Women Watch (2018), "Facts & figures: Rural women and the millennium development goals", webpage, www.un.org/womenwatch/feature/ruralwomen/facts-figures.html (accessed 20 August 2019).

Vadillo, N.S., O. Esteban and M. Vall-Llovera (2012), Breaking the gender digital divide. Involved factors in the choice of a technological career [Romper la brecha digital de género. Factores implicados en la opción por una carrera tecnológica], *Athenea Digital*, Vol. 12(3), pp. 115-128, https://ddd.uab.cat/record/112160.

van Baak, C. and B. Hayes (2018), "Correlates of cyberstalking victimization and perpetration among college students", *Violence and Victims*, Vol. 33 (6), pp. 1036-1054, https://doi.org/10.1891/0886-6708.VV-D-17-00073.

van Oosten, J. M. F., Peter, J., and P. M. Valkenburg, (2015), "The influence of sexual music videos on adolescents' misogynistic beliefs: The role of video content, gender, and affective engagement", *Communication Research*, Vol. 42(7), pp. 986–1008, https://doi.org/10.1177/0093650214565893 .

Wajcman, J. (1991), *Feminism Confronts Technology*, Cambridge: Polity Press.

Webfoundation (2015), Women' Rights Online – Translating Access into Empowerment, WorldWideWebFoundation, http://webfoundation.org/docs/2015/10/womens-rights-online21102015.pdf (accessed on 8 June 2019).

Weinberg, B. (2000), "Computer use and the demand for female workers", *Industrial and Labor Relations Review*, 53(2), 290-308, https://doi.org/10.2307/2696077.

Wigfield, A. and J. Cambria (2010), "Students' achievement values, goal orientations, and interest: Definitions, development, and relations to achievement outcomes", *Developmental Review*, Vol. 30/1, pp. 1-35, https://doi.org/10.1016/j.dr.2009.12.001.

Wladis, C., A. Hachey and K. Conway (2018), "No Time for College? An Investigation of Time Poverty and Parenthood", *The Journal of Higher Education*, Vol. 89:6, pp. 807-831, https://doi.org/10.1080/00221546.2018.1442983.

Wood, R.T.A. et al (2004), "Video game playing and gambling in adolescents: common risk factors", *Journal of Child & Adolescent Substance Abuse*, Vol. 14/1, pp. 77-100, https://doi.org/10.1300/J029v14n01_05.

Worldskills (2019), World Skills Survey "Youth Voice for the Future of Work – Global Report", webpage, https://worldskills.org/ (accessed on 24 July 2019).

WEF (2015), *The global gender gap report 2015*, World Economic Forum, Geneva, Switzerland, http://www3.weforum.org/docs/GGGR2015/cover.pdf (accessed on 14 June 2019)

Weisseman, J. (2018) "Amazon Created a Hiring Tool Using A.I. It Immediately Started Discriminating Against Women", webpage, https://slate.com/business/2018/10/amazon-artificial-intelligence-hiring-discrimination-women.html (last accessed 24 August 2019)

Weitzer, R., and C. E. Kubrin (2009), "Misogyny in rap music: A content analysis of prevalence and meanings", *Men and Masculinities*, Vol. 12(1), pp 3–29, https://doi.org/10.1177/1097184X08327696.

West, S.M., Whittaker, M. and K. Crawford (2019). "Discriminating systems: Gender, Race and Power in AI", *AI Now Institute*, https://ainowinstitute.org/discriminatingsystems.html (accessed on 24 August 2019).

Xu, H. et al. (2018), "Latent Class Analysis of Recurrent Events in Problem-Solving Items", *Applied Psychological Measurement*, 42(6), 478-498, https://doi.org/10.1177/0146621617748325.

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