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The digital revolution: Implications for gender equality and women's rights 25 years after Beijing

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Introduction

The digital revolution, alongside new risks and challenges, brings immense potential to improve social and economic outcomes and enhance productivity growth and population well-being globally. However, despite a number of important interventions and policies aimed at furthering women's empowerment and gender equality within this 'revolution', a significant digital gender gap (still) exists, limiting the equitable realisation of the benefits of digital transformation (OECD, 2018). Analysis from the EQUALS research group, led by the United Nations University (UNU), shows that 'a gender digital divide persists irrespective of a country's overall ICT access levels, economic performance, income levels, or geographic location' (Sey and Hafkin, 2019: 25). Women are underrepresented in the digital revolution across high, low and middle-income countries.

To address this digital gender divide, much more attention needs to be paid to the structural factors (economic, social and political) that underpin the development, design and use of digital technologies. The digital transformation holds the promise of greater gender equality but, at the same time, poses the risk of repeating and amplifying existing patterns of gender *inequality*. This paper illustrates how digital technologies shape, and are shaped by, gender relations and gendered power structures. It then identifies potential risks and opportunities, presenting recommendations for shaping technology in ways that prevent harm and instead contribute to advancing gender equality and women's rights in the digital age. In the body of the text we examine three substantive areas: education, work and social/welfare services.

The digital revolution

Over the last 25 years, the rapid development and spread of digital technologies has been pervasive across almost every aspect of socio-political and economic life, including systems of governance, communications and structures of production and consumption. The digital revolution, marking the shift from analogue to digital technologies, is characterised by technological advances ranging from smart phones, the mobile internet, and the Internet of Things (IoT), to Artificial Intelligence (AI) and machine learning, (big) data and social media, cloud computing and robotics. These span public and private industries including healthcare, commerce, education, manufacturing and finance. This 'fourth industrial revolution' has brought with it a new digital economy across developed and developing economies alike (Schwab, 2016).

'All of these advances suggest that life in the remainder of the twenty-first century will increasingly be arranged around interactive, individualised digital technologies in the same way that life in the twentieth century was shaped around mass broadcast technologies of the television, telegraph and radio', proposes Selwyn (2017: 17). Data-driven, digital technology has changed the way people communicate, inform themselves, and relate to each other (Turkle, 1984, 2011); it has shaped our experiences of time (Wajcman, 2015); expanded existing and new forms of activism (Friedman, 2016); affected governance systems, including the ways in which public services are delivered; altered production and consumption patterns with far-reaching implications for the world of work (ILO, 2019); and led to the rise of 'big data' as a valuable material that is mined to support new forms of capitalist accumulation (Zuboff, 2019). More recently, AI, underpinned by algorithms and machine learning, has become a defining feature and driving force of the data-driven, digital revolution.

As with previous periods of rapid technological change, digitalisation has provoked both utopian and dystopian visions of the future. 'Digital technologies are rapidly transforming society, simultaneously allowing for unprecedented advances in the human condition and giving rise to profound new challenges. Growing opportunities created by the application of digital technologies are paralleled by stark abuses and unintended consequences' (UN Secretary-General's High-level Panel on Digital Cooperation, 2019: 4). Over the past decade, new risks and challenges related to fairness and inclusion, (data) privacy and autonomy, accountability and transparency have become increasingly clear (The Alan Turing Institute, 2019).

While the internet was initially viewed as a democratising platform, for example through citizen reporting of news and information sharing, such early emancipatory promises increasingly ring hollow as a small group of large (platform) technology corporations based in the Global North, have emerged as a dominant controlling force in the new global economy. These 'tech giants' monopolise markets and wield power over digital data, as major online platforms are found complicit in the spread of misinformation, hate speech and online harassment. In particular, there are concerns that unprecedented levels of data mining, or 'data extractivism', algorithms, and predictive risk models could entrench existing inequalities and power dynamics, threaten individual rights and enable new forms of surveillance by governments and corporations (Eubanks, 2018; Zuboff, 2019).

In order to mitigate these emerging issues within the digital revolution, digital technologies cannot be understood as separate tools, but as part of a wider, changing structural context that shapes their design, purpose and use. This is particularly important at a time when digital tools are often marketed as solutions to socio-political problems. But technologies are not neutral or value-free, and thus there are opportunities to shape them in ways that prevent harm. As data-driven technologies touch on almost every aspect of economic, social and political life in the Network Society (Castells, 1996), attention must be drawn towards the ways in these digital tools can be directed towards advancing equality, in particular, women's rights in the digital age. At a moment when technology is being marshalled to make choices of global consequence, and is affecting the lives of individuals and society in ways both profound and subtle, this warrants urgent attention (West, Kraut and Chew, 2019).

The digital revolution and gender: a conceptual framework

Early feminist responses to the digital revolution were largely optimistic about the potential of digital technologies, particularly Information and Communication Technologies (ICTs), to empower women and transform gender relations. Cyberspace seemed like a new gender-neutral space – a democratizing and emancipatory platform. In many ways it is, and mobile phone technologies in particular have been found to benefit women in their access to information and facilitating collective action.

As such, a number of initiatives and projects have been put in place to track and advance women's digital empowerment. For example, GSMA's 'Connected Women' programme works with mobile operators to address the barriers to women accessing and using mobile internet, in particular mobile money services, in low and middle-income countries (LMICs) (Rowntree, 2019). Additionally, the 'Digital Gender Gaps: Measuring digital gender inequalities in real-time' project aims to track progress on gender inequalities in

internet and mobile access and usage, measuring women's participation in the digital revolution. Acknowledging the wide-ranging potential of digital technologies, in particular mobile phones, the UN Sustainable Development Goals (SDGs) pledged to 'enhance the use of...information and communication technology to promote the empowerment of women' (Goal 5b).

Despite the good intentions and partial successes of these initiatives, however, inequalities in access to ICTs, and moreover men's control over women's use of ICTs, continue to persist (Sey and Hafkin, 2019). It is estimated that women's access to the Internet and mobile phones is about 85% of the level for men, on average, and that a total of 1.7 billion women in the Global South are unconnected (Devillard, Madgavkar and Bush, 2018). Worldwide roughly 327 million fewer women than men have a smartphone and can access mobile internet (OECD, 2018).

The language of 'ICTs for women's rights' - along with other initiatives which work towards women's digital empowerment - is often framed too narrowly as an 'access' issue. Feminist critiques of ICT4D emphasise the need to move beyond issues of access (and affordability) to address questions of power and inequality (Tongia, Subrahmanian and Arunachalam, 2005). Moreover, such initiatives often overlook the way gender intersects with other aspects of difference and disadvantage - within which these technologies sit.

Moreover, many discussions of digital technologies, particularly those presented by technology developers themselves, often make technologically deterministic claims about technology's 'effects', rarely asking what technology 'is', and how it 'comes to be' (Oliver, 2016: 35). Understanding digitalisation only as the *effects* of technology ignores the complex processes of how technologies are socially shaped in their very design and in use. Which technologies have been developed and will be developed are fundamentally shaped by the minds, hands, and culture of people and, therefore, reflect history, context, choices, and values (Mackenzie and Wajcman, 1999; Hackett et al., 2008). As such, digital technology should be conceptualised as a socially constructed, sociotechnical product, shaped in action, through its design as well as its everyday use (Suchman, 2007).

A social shaping conceptual framework, understood through an intersectional, (techno)feminist lens signals an explicit move away technological determinism by acknowledging the complex interplay between gender and digitalisation. It explores how digital technologies can be harnessed for accelerating progress towards gender equality and equal opportunity, rather than becoming assimilated into dominant power structures (Gurumurthy, Chami and Billorou, 2018). As technology and society are mutually shaped,

it follows that 'gendered power relations' and gendered meanings are inscribed into technologies (Wajcman, 2006). Gender power relations will influence the process of technological change, which in turn configures gender relations. In other words, 'women's identities, needs and priorities are configured together with digital technologies' (Wajcman, 2010: 149 - 150). As much research in feminist science and technology studies suggests, technologies are gendered by association and by design, where 'association' refers to the gendering of work environments, and technology stereotypes (Faulkner, 2001; Henwood, 2000). In this way, 'gendered practices' mediate the digital revolution and the political and socio-economic roots of the networks that shape and deploy technological systems.

Feminist scholars researching at the intersection of gender and technology examine the ways in which people produce, sustain and challenge gender identity within science and technology. For example, gendered norms have been shown to shape and circumscribe scientific insights (Haraway, 1988); and gendered identities are found to be co-constructed with technologies and technical orientations (Bardzell, 2018; Pérez-Bustos, 2018) - often in connection with alignments of race and class (Noble, 2018; Benjamin, 2019). The experience of women is not universal, and it is necessary to pay attention to intersections of gender, race, class, sexuality, disability and age (Buolamwini and Gebru, 2018; Tulshyan, 2019). Scholars have also explored how gender categories generate variations in experience that produce, or further entrench, structural inequalities in the STEM fields, such as Rossiter (1993) who charts women's exclusion from developments in science and technology. As we note later, in the early days of computing, women were considered the ideal workers for these jobs.

If 'technology as such is neither inherently patriarchal nor unambiguously liberating' but socially shaped, then feminist analysis must pay attention to the economic, social and political circumstances that influence the development and use of digital technologies in the current era (Wajcman, 2010: 148). This era is marked by persistent poverty and rising inequalities; democratic backsliding, including reversals of progress on gender equality and women's rights; welfare state retrenchment and austerity; and the increasing power of corporations. Gender, and gender-based digital exclusion, must be located within these broader structural trends and institutional changes. This in turn requires a move beyond the focus on strengthening women's access to and use of digital technologies, on the one hand, and 'getting more women in tech', on the other. The focus should be on harnessing digital technologies for accelerating progress towards gender equality, rather than becoming assimilated into dominant structures of power.

(Dis)empowerment: women's place in the digital revolution

Digital technologies could improve female participation in economic life and enhance the economic and social autonomy of women. Mobile and digital technologies offer women the potential to bypass some of the traditional cultural and mobility barriers, particularly in low and middle-income countries (Sorgner and Krieger-Boden, 2017). For example, women unable to join to the main protests during Sudan's protest movement, particularly rural women who are typically hemmed in by deeply rooted patriarchal structures, recorded and shared their support for the movement on social media, such as Facebook and Twitter. In Rwanda, over 3,500 women farmers are now connected through mobile technology to information, markets and finance (Mlambo-Ngcuka, 2017).

Yet at the same time, there are worrying signs that the digital gender divide is widening (West, Kraut and Chew, 2019). Hurdles including (lack of) education as well as inherent biases and socio-cultural norms located within existing (masculine) power structures curtail women and girls' ability to benefit from the opportunities offered by the digital revolution (OECD, 2018). In the Global South, mobile phone ownership has not only been linked culturally to promiscuity for girls, but also has implications for misogynistic online abuse and harassment through social media apps for women. In Saudi Arabia, the Absher App has been (ab)used by men to track and control their women dependent's movement, reinforcing the country's system of male guardianship (Robertson and Ayazi, 2019).

The systemic conditions that perpetuate patterns of conscious or unconscious discrimination against women within the digital society must be addressed. This paper will now focus on three areas to illustrate how digital technologies shape (and are shaped by) gender (in)equality in order to identify opportunities and risks in the digital revolution: education, work, and social/welfare services.

1. Education (and lifelong learning)

The rise and widespread dissemination of digital technologies shapes gender (in)equality in the educational sphere in a multiplicity of ways, across the educational life-course. This occurs across a number of interrelated 'moments'. These include limited access for girls in under-developed economies to educational opportunities, both with and without technologies; gender inequalities in digital literacies (the digital skills gender gap), the limited number of women in STEM programmes (Ertl and Helling, 2012); and the 'masculine' cultural associations with a STEM education, and related gendered identities, stereotypes and biases (Master, Cheryan, and Meltzoff, 2016; Stoet and Geary, 2018). The masculine construction of computing expertise in particular leads to a gendered digital, computing culture, shaping 'gendered spaces' across the educational life-course (as well as in the workplace) (Margolis and Fisher, 2002). 'Certain gendered norms govern technical participation and how other gendered identities are left out, producing continuing absences in the field' (Rosner, 2019). This in turn reinforces gender deficits in the STEM pipeline into future technological development in the workplace.

The digital skills gap

The digital gender divide, once defined by inequalities in access to digital technology, has been eclipsed by deficits in learning and skills (West, Kraut and Chew, 2019). Whilst there is still an 'access gap' between men and women, particularly in the Global South, there has been widespread increased access to digital technologies for women in the past 25 years. Nevertheless, the gender 'digital skills gap' persists. Despite a number of important interventions and policies aimed at achieving gender equality in digital skills across both developed and developing economies, a divide remains large and, in some contexts, is growing wider still. This skills divide is underpinned by a deficit in digital literacies for women, particularly in low and middle-income countries, where many women lack the necessary techno-social capabilities to compete in a global online environment (Gurumurthy, Chami and Billorou, 2018).

Education has a key role to play in helping women and girls to develop their digital skills and gain confidence in gender-responsive learning environments. Globally, many women and girls can afford technology but do not know how to leverage it for empowerment. This is the case from the most basic levels of proficiency, to the most advanced skills in frontier areas such as AI and machine learning. 'Women fall off every rung of this skills continuum, so that by the time learners reach the vanguard of technology creation where norms, protocols and processes are shaped, women are almost entirely absent' (West, Kraut and Chew, 2019: 64 – 65). The skills gap widens in secondary and tertiary education, and lower proportions of women graduate in engineering and ICT subjects (see figure 1) (Varma, 2010). Girls' relatively lower educational enrolment and graduation in the STEM disciplines that would allow them to thrive in a digital world suggests widening gaps and greater inequality perpetuating a vicious cycle, especially in disadvantaged areas.

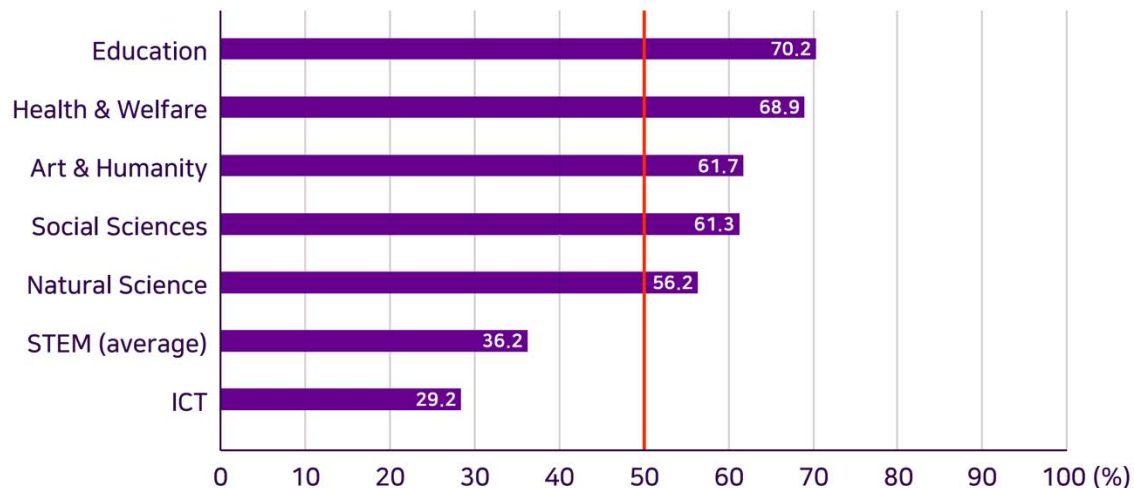


Figure 1. Global proportion of female enrolments by field of study (EQUALS Research Group; West, Kraut and Chew, 2019)

A variety of initiatives have been trialled in the past few decades in developed economies to encourage a more diverse participation in technological fields within Higher Education. Particularly notable are the successful models provided by Carnegie Mellon and Harvey Mudd (American Universities) who have dramatically increased the participation of women in their computer science departments. For example, Carnegie Mellon increased the number of women from 7% in 1995 to 42% in 2000. This suggests how straightforward steps towards resolutions of the issues can be with the right policies and leadership in place.

In developing economies, however, the issue is more complex. Here, the social, political and economic challenges can be myriad and overlapping. Women and girls may not have the financial independence needed to purchase digital technologies (or pay for internet connectivity), and many struggle to access public ICT facilities due to limits on their freedom of movement or unsafe roads. 'Digital access, even when available, may be controlled and monitored by men', explain West, Kraut and Chew (2019: 37). But when attention is paid to the right structural factors, change can happen (Devillard, Madgavkar and Bush, 2018). A recent study on women's digital literacy in Indonesia, for instance, shows that teaching women how to create content and share information on digital media can open up opportunities for economic and professional growth (Suwana and Lily, 2017).

Concerted efforts to close the digital skills gender gap can help countries meet their international commitments to education and gender equality. Alongside gender equality (in gaining digital literacy) as a fundamental human right, learning digital skills can also impact on women's ability to participate in government and politics, and engage more actively with their communities. There are also a number of economic benefits, from enabling women to enter and compete in the labour market and reducing the gender wage gap, to increasing profits, productivity and innovation for technology companies.

Digital skills education programmes should strive not just for gender sensitivity, but rather for gender-transformative approaches. Education can shift the 'tech is for boys' narrative that often guides girls' and

women's' interests, perceptions of their own aptitude, decisions about fields of study, career paths, and professional aspirations. Indeed, the EQUALS skills coalition, a multi-stakeholder initiative across the public and private sectors, promotes gender balance in the technology sector by championing equality of access and, more importantly, skills development. Additionally, the Global Fund for Women's technology initiative works towards not only 'closing the gender gap' in access and crucially, control and shaping, of technology, but also empowering women through STEM and IT education investments. The Women's Rights Online (WRO) network within The World Wide Web Foundation is also a research and advocacy network that aims to drive women's empowerment through the internet. Digital skills and literacies are necessary - but not sufficient - conditions for women to meaningfully harness digital technologies for their social and economic empowerment.

Education technologies

Technological innovations in the last few decades have altered today's educational landscape. Digital learning technologies can impact how, what and where students learn, and facilitate (or inhibit) access to educational opportunities, both formally and informally (Selwyn, 2013; UNESCO, 2015). Educational technology ('edtech'), including personalised learning platforms, educational games, interactive whiteboards and online courses, can be leveraged across high, low and middle-income countries to help women and girls navigate the digital economy in different ways (Emejulu and McGregor, 2016; Escueta et al., 2017). Implementing digital technologies in pedagogy, particularly in schools, however, requires a critical understanding of each country's economic, political, social and cultural climates.

Internet access and digital technologies can be used by women and girls for lifelong distance learning and training in low and middle-income countries. Online learning platforms have the potential to open up new opportunities to women, particularly in rural and resource-constrained environments with limited access to formal educational and training institutions. For example, 'Making Ghanaian Girls Great!' (MGCubed) is Ghana's first interactive distance-learning project. Funded by the Department for International Development (DFID)'s Girls' Education Challenge (GEC), the MGCubed Project uses solar-powered and satellite-enabled distance learning infrastructure to deliver interactive learning sessions to students, teachers, communities and government officials. Learning Equality has also created tools for low-income countries such as Kolibri, an open-source educational toolkit, and KA Lite, an offline version of Khan Academy. Additionally, in the Republic of Moldova, GirlsGoIT teaches girls digital, ICT and entrepreneurial skills, and promotes positive role models through video. In adult learning, UN Women have developed WeLearn, a Virtual Skills School for women and girls who had to previously leave formal education.

While such online platforms have much potential, there needs to be greater awareness of how gender scripts are embedded in educational tools (by instructional designers), reinforced in classroom practices, and thus shape learner experiences (Heemskerk et al., 2009). Studies have also found gender differences in teachers' use of digital technologies across the educational life-course. For example, Zhou and Xu (2007) found that women had lower confidence in the use of computers in teaching in Higher Education. Educational technologies can be harnessed to encourage greater gender equality through teaching and learning, but broader gender relations across contexts must be consistently understood and addressed in order to advance this.

Masculine associations with STEM and digital fields

Cultural associations between masculinity and technological skill, and femininity as ‘incompatible’ with technical pursuits, persist across the digital landscape worldwide.¹ The stereotype of technology and engineering as a male domain is pervasive across educational contexts, affecting girls’ confidence in their technical skills and shaping their perception of their own identity (and proficiencies) within the digital revolution.

This social construction of digital expertise in particular leads to a gendered computing culture, shaping ‘gendered spaces’ across the educational life-course (Margolis and Fisher, 2002). Gendered norms and (sub)conscious biases govern technical participations and absences in STEM and ICT education, across the lifelong learning life-course (which in turn reinforces gender deficits in the STEM pipeline into future technological development in the workplace) (Phipps, 2007). The limited number of women in educational STEM programmes, heavily contributing to the digital skills gap, as presented above, is underpinned by this stereotyping of ‘what it takes’ to be successful across the technical educational life-course in a digital world (Hill, Corbett and St. Rose, 2010).

There are a growing number of organisations working to promote gender equality in education and technology across the world, including WISE, Athena SWAN, Black Girls Code, and Girls who Code. Despite a range of initiatives, however, there is a lack of coherent policy promoting the participation of women and girls in technology across the educational landscape. This impedes formal training and institutional mechanisms for the advancement of women in STEM education and, in turn, the deficit of women in academia researching in technical fields. For example, a joint study by WIRED and Element AI found that only 12% of authors publishing in the leading three AI conferences in 2018 were women (Hudson, 2018) (see figure 2). Women are also under-represented at 17-18% across the growing online data science development platform communities, such as DS Central, Kaggle and OpenML. In a large-scale analysis of gender diversity in AI research using publications from arXiv, Stathoulopoulos and Mateos-Garcia (2019) found a severe gender diversity gap in AI research. If the hierarchies, relations and pervasive gender stereotypes shaping these marked inequalities across the educational life-course persist, digital technologies risk becoming further assimilated into the dominant structures of power within Education, and beyond.

¹ West, Kraut and Chew (2019) point out that Arab countries have between 40 – 50% female participation in ICT programmes (a proportion far higher than many of the more gender-equal European countries). However, this is not representative of the broader trends worldwide, which are far lower.

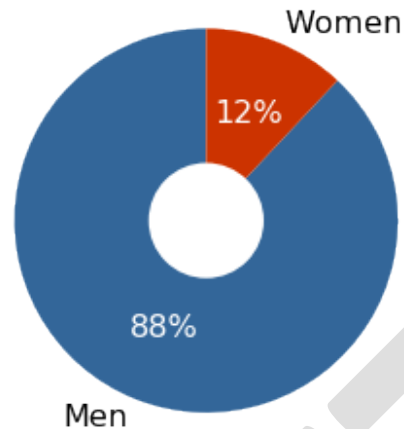


Figure 2. Contributions to the top three AI conferences (WIRED and Element AI, 2017).

2. Work

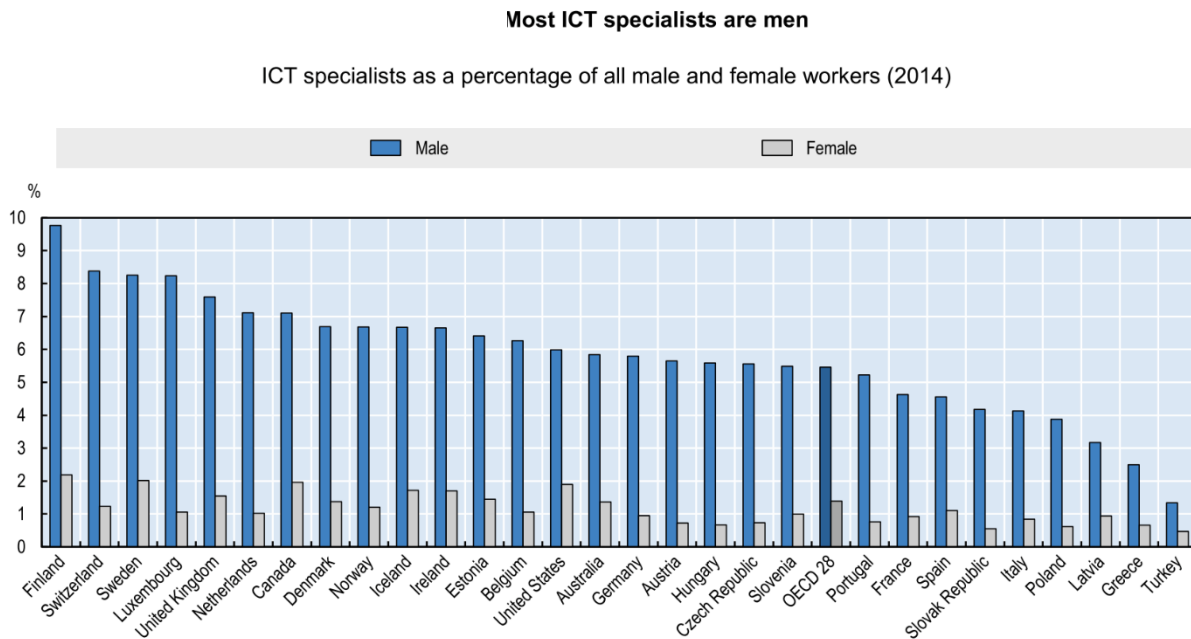
The digital revolution holds the promise of greater gender equality in education, at the same time as posing the risk of amplifying existing patterns of gender *inequality*. This is also the case in the world of work. The discussion of education above set the scene for the ‘pipeline problem’ of getting women ‘into’ the technology labour market in order to move towards women’s equality in the digital gender divide. But education on its own will not solve the problem: stereotypes and gendered spaces, shaped by (and shaping) structural, gendered relations and associations in the educational sphere are brought forward, and often magnified, in the workplace.

This not only further negates opportunities for women to harness the digital revolution for their empowerment, but also risks widening the digital gender divide, as corporate technology giants increasingly dominate the new global economy. The structural inequality of opportunity for women in the workplace, severely limiting their participation in the design and development of new digital technologies, partakes in a feedback loop which further constructs, and amplifies, biases against women. As we shall see, this is magnified in emerging AI systems, both through the oncoming wave of AI technologies automating existing job roles (and the need for women to re-skill into new careers), and through the presentation of these technologies as ‘objective’, decision-making tools.

The workplace

There are notable disparities in the gender diversity of technological workforces across OECD countries (see figure 3). Gendered divisions of labour around technology are, as previously noted, based in part on equations around masculinity and technical skill. However, the masculine culture of the workplace itself

is a key factor in women’s under-representation in technological pursuits. In particular, stereotypes about digital, technical skills, including the ‘brogrammer’ and ‘geek’ cultures synonymous with Silicon Valley, hinder women’s career progression (Jacobs, 2018).



Notes: ICT specialists are defined as individuals employed in “tasks related to developing, maintaining and operating ICT systems and where ICTs are the main part of their job”. ICT specialists’ figures are based on the following ISCO-08 3-digits occupations: 133, 215, 25, 35, 742. OECD aggregate is a weighted average for all countries for which data are available.

Source: OECD (2016b).

Figure 3. ICT specialists as a percentage of all men and women workers (OECD, 2017)

Several studies have revealed subtle cultural practices embedded within technology workplaces which lead to ‘chilly’ workplace climates for women and minorities (Hill, Corbett and St. Rose, 2010; Berman and Bourne, 2015). The prevalence of ‘masculine defaults’ in these spaces results in micro-aggressions, subconscious biases, sexual harassment and other forms of discrimination such as demeaning comments (Alfrey and Twine, 2016). For instance, in 2018 Google staff walked out over how sexual misconduct allegations are dealt with at the firm (Lee, 2018). More recently Alphabet, the parent company of Google, rejected several proposals to address sexual harassment and boost diversity at its annual shareholder meeting (Paul, 2019). Awareness of these issues alone does not necessarily lead to corporate (or governmental) policy changes.

In turn, this ‘technoculture’ has significant repercussions for recruitment, promotion, career trajectories and pay. For example, Wynn and Correll (2018) suggest that women are alienated at the point of recruitment into technology careers. They found that company representatives often engage in behaviours, such as geek culture references, that create ‘chilly’ environments for women prior to joining a firm. Additionally, there is a significant pay gap in technology fields. For example, in the UK it is estimated

to be 16.8%. Furthermore, once women are employed in technological fields, the rate of attrition is high. A 2016 study from the US National Centre for Women Information Technology found that women leave technology jobs at twice the rate of men (Ashcraft, Mclain and Eger, 2016). In a similar vein, McKinsey found women made up 37% of entry-level roles in technology, but only 25% reached senior management roles and 15% made executive level (Krivkovich, Yee and Kutcher, 2016).

There is also a severe under-representation problem in entrepreneurship. This, almost paradoxically, is often heralded as the way for women to 'get ahead' in the digital revolution. Female founders in the USA received only 2% of Venture Capital dollars in 2017, according to data from VC database PitchBook (Zarya, 2018). In Europe, Atomico also found that 93% of all start-up funds raised in Europe in 2018 went to all-male founding teams – with just 2% to all-female founding teams.

Recently, women and other marginalised groups have slowly been making inroads back into computer science in professional capacities. However, the same patterns that presented themselves in the earliest days of the field may be about to occur again. At the advent of electronic computing following the Second World War, software programming in industrialised countries was largely considered 'women's work', and the first 'computers' were young women (Abbate, 2012). Structural discrimination, however, shifted the gender composition of the computing industry, marginalising the work of female technical experts by fashioning them into a technical 'underclass'.

As women have begun to enter certain technological subdomains in more recent years (often through boot camps and other atypical educational pathways), these fields have started to lose prestige and experience salary drops (Posner, 2017; Broad, 2019). Meanwhile, men are flocking to the new (prestigious and highly remunerated) fields of data science and AI. This annexing of prestige fields, at the frontiers of technological development, is closely related to the gender pay gap (Lordan, 2018), and the prevalence of men in decision-making spaces in technology companies. As Hicks (2017: 16) notes, 'throughout history, it has often not been the content of the work but the identity of the worker performing it that determined its status'.

In these ways, the lack of women in the high-tech sector, particularly in leadership positions, risks the cyclical perpetuation, or even amplification, of structural gender inequalities. A recent UN Women publication suggests that 'gender-inclusive industrial policies can help ensure that women maintain access to these jobs as they get better, on both the demand and supply sides' (Elson and Seth, 2019: 93). On the demand side, such interventions would create incentives for upgrading firms to employ women or support women's leadership and voice in industry. On the supply side, ensuring women's inclusion in efforts to enhance learning and capabilities in industrial sector activities is key.

Initiatives for professional women in technology across high, low and middle-income countries, such as Women in Technology Uganda and Women who Code, have been established to encourage women's inclusion in the technological workforce. Such drives alongside labour force policies are needed to ensure that conscious and unconscious biases and inequalities in the workplace do not shape the technologies constructed within these spaces, further assimilating them into dominant, masculine power structures. Otherwise, opportunities for women to harness the digital revolution for their empowerment will be negated, and risk widening the digital gender divide, as corporate technology giants increasingly dominate social, political and economic life.

Precarious work arrangements

While discussions about the impact of automation on the future of work are generally about job creation versus job loss, digitalisation's impact on the quality of work receives less attention.² However, with the rise of the 'gig' or 'platform' economy, the digital revolution marks a shift in the labour market (OECD, 2017).³ Automated systems have facilitated a major expansion of one-off contracts for specified services and tasks, particularly through online platforms such as Amazon Mechanical Turk (MTurk) and Upwork. As shown in figure 4, workers providing services on online platforms are mostly located in low-income countries. Women are also disproportionately represented in these 'non-standard' forms of employment, as they provide increased flexibility for those with care responsibilities, for example. However, this reorganised labour is highly un-regulated, and is characterised by low and intermittent pay, unpaid time spent searching for tasks, as well as exclusion from social protection and employment standards. As work becomes more fragmented, there is also increased competition for each new task. Policy must ensure that online platforms provide real opportunity, rather than substituting a traditional 'sweat shop' for a digital one.

Digital service workers on online platforms are mostly located in low-income countries

Top 10 employer and provider countries on Upwork, 2014



Notes: Upwork is one of the leading global freelancing platforms. Top 10 employer (provider) countries are denoted by their flags and two-digit international codes. Circular arrows denote flows where employer and provider countries coincide.

Source: OECD (2016a) based on Upwork, 2015.

Figure 4. Upwork employer and provider countries (OECD, 2017)

Changes to the nature and quality of work for women through the digital revolution is also uncovered through what Gray and Suri (2019) term 'ghost work'. 'Ghost work' represents the vast, 'invisible' human

² McKinsey (2019) call for government and industry investments in re-skilling and increasing gender balance as 40-160 million women may need to transition to new occupations by 2030. Unpaid care work burdens make making time for this more difficult for women than men, however.

³ Wood (2016) refers to this gig work as offering 'temporal flexibility'.

labour force (often behind 'smart' AI) who carry out skilled technological work such as labelling data to feed algorithms, cleaning code, training machine learning tools, and moderating and transcribing content. For example, mostly invisible by design, more than 100,000 commercial content moderators evaluate posts on social media platforms, actively screening and removing offensive material (Roberts, 2019). These 'ghost workers', often women in the Global South, are underpaid and undervalued. Lacking labour laws, the majority of this 'unseen' workforce have no health benefits, and can be fired at any time for any reason, or none.

The case of AI

Artificial Intelligence (AI) is again attracting significant attention in academic, policy and commercial fields across all areas of social life. Since its' inception in the 1950s, AI and the possibility of programming an electronic computer to behave intelligently has captured the attention of many groups of people (Russell and Norvig, 2002; Buchanan, 2005). Whilst the current 'AI summer' holds much promise, there is a growing concern not only that women and other marginalised groups will not equally benefit, but also that it might actually cause more harm.

The structural inequality of opportunity for women in the (technological) workplace severely limits their participation in the design and development of the emerging AI technologies themselves (Leavy, 2018). Most digital technologies, including AI systems, are designed by the few for the many, and as such there is a severe risk that they inherently (yet not deliberately) consolidate existing, often invisible, power dynamics (see figures 5 - 7). As the European Commission has emphasised: 'Technology reflects the values of its developers, and that of the information they draw from. It is clear that having more diverse teams working in the development of such technologies might help in identifying biases and prevent them' (Quirós et al., 2018).

More gender-equal technology design and development teams are, on the whole, better positioned to create more gender-sensitive technology that is also likely to be more innovative and profitable. Since 'women are largely excluded from processes of technical design that shape the world we live in' (Wajcman, 2006: 145), gender bias inevitably shapes the socio-technical systems and networks in which technologies are developed. The lack of diversity in the technology industry and the (resulting) emerging constructions of bias, particularly in algorithms and other systems produced within the field of AI, are thus deeply intertwined.

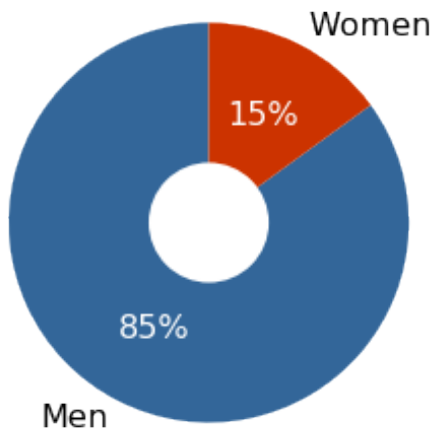


Figure 5. Facebook's AI workforce (company reported statistics, 2018)

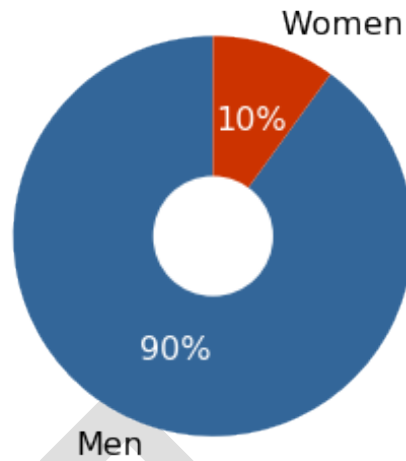


Figure 6. Google's AI workforce (company reported statistics, 2018)

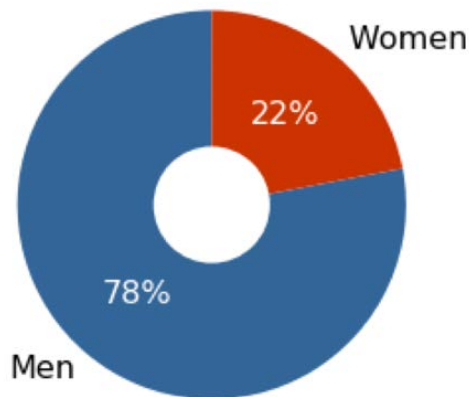


Figure 7. Global AI workforce (World Economic Forum and LinkedIn data, 2018)

For example, gender-biased AI has emerged in facial recognition software that successfully identifies the faces of white men but fails to recognise those of dark-skinned women (Raji and Buolamwini, 2019). Bolukbasi et al. (2016) found that machine learning and natural language processing (NLP) runs the risk of amplifying data biases. Word embeddings trained on Google News articles exhibit female/male gender stereotypes, gendering computer programmers as male and home-makers as female. Gender-biased AI has also emerged in science career job advertisements, which (gendered) marketing algorithms prevent many women from seeing (Maron, 2018). Amazon's hiring algorithms were also found to discriminate

against female applicants (Dastin, 2018; ILO, 2019). Finally, apparently neutral online spaces (and infrastructures), such as Wikipedia, have been challenged as excluding women's voices (Ford and Wajcman, 2017).

The ubiquitous female gendering of digital Virtual Personal Assistants (VPAs), for example, Alexa and Siri, is another case in point. While developers justify this by citing 'likeability', pre-existing stereotypes (embedded within existing power structures) about the role of women as obedient, subservient and 'domesticated' are further entrenched (Saran and Srikumar, 2018; Specia, 2019). Research has also showed that when image-recognition software was trained on sets of photos that displayed gender bias - in this case, a disproportionate representation of women cooking and men playing sports - the software not only mirrored the gender bias, but amplified it, creating a stronger association between gender and activities than was found in the original photo set (Simonite, 2017).

The pernicious problem here is that AI presents as objective and 'neutral' in decision-making, when really there are embedded values – in particular, masculine value systems. 'The diversity crisis in the industry and the problems of bias in AI systems are interrelated aspects of the same issue' (West, Whittaker and Crawford 2019: 32). Machines trained with datasets, and potentially biased algorithms, can amplify existing biases, turning human prejudices into seemingly objective facts. If primarily white men are setting AI agendas and developing AI tools, and many data sets (unintentionally) marginalise women, it follows that supposedly 'neutral' technology and data are bound to be inscribed with masculine preferences (Zou and Schiebinger, 2018; Criado Perez, 2019). A 'feedback loop' is shaping the AI industry and its tools, and thus a gendered vision of the world is being inscribed in AI technologies.

Gender imbalances in the AI sector are thus being 'hard-coded' into digital technology products. It is imperative that the designers of AI are more representative of society at large to begin 'un-gendering' AI technology. Indeed, the Lords AI Committee (2017) in the UK urges for gender and ethnic diversity amongst AI developers to tackle this.

It is also essential that the ethics of design include intersectional gender issues. We must 'ensure that Artificial Intelligence is a field that is inclusive by design' (WEF, 2018: 32). The Gendered Innovations project, for example – arguing that gender analysis needs to be part of research and development design - seeks to develop methods of sex and gender analysis for scientists and engineers. Shaping emerging digital systems, platforms and tools, particularly AI, in such ways can mitigate the emerging risks of perpetuating gender inequalities, contributing to advancing women's rights in the digital age. It will ensure that new technologies are not further constructing existing and dominant, often unconsciously unfair, structures of power.

3. Social and welfare services

Women are disproportionately more likely to be in need of public, social and welfare services, due to their greater care and domestic responsibilities. Therefore, it is crucial to examine the emerging and widespread dissemination of AI not only within private sectors, but across public sectors too. Marginalised people, most prominently women in deprived areas across the world, are most reliant on welfare services. In developed economies, the digital revolution has brought with it data-driven, automated systems (based on predictive models) which make decisions regarding social services; for example, determining who

should receive state welfare payments. Artificial intelligence is now used to automate decision-making from the health care industry to the legal system, and may be responsible for 'making choices that affect people's life trajectory, such as which medical treatment they receive [or] whether they are eligible for life insurance or a loan' (West, Kraut and Chew, 2019: 33). Digital technologies are increasingly enmeshed in social policy and service delivery, particularly for society's disadvantaged in the USA, augmenting operations of welfare payments, homeless services and family support and child protection services.

As Eubanks argues, automated eligibility systems and predictive analytics embed, reproduce and reinforce gender, class and racial distinctions within what is presented as an 'objective' automated tool. Even if designed with the best of intentions, they 'do not remove bias, they launder it, performing a high-tech sleight of hand that encourages use to perceive deeply political decisions as natural and inevitable' (Eubanks, 2018: 224).

As touched upon above, when deep learning systems are trained on data that contain gender biases, these biases are reproduced in the software. Yet they are presented as 'neutral' decision-makers. Fei-Fei Li, a prominent researcher in the AI field, explains simply that such systems are 'bias in, bias out' (Hempel, 2018). One attempt to counter this is the data2x project which aims to improve the 'quality, availability, and use of gender data in order to make a practical difference in the lives of women and girls worldwide'.

A major problem is the broad lack of transparency on the part of big technology companies as well as digital public services (Vaidhyathan, 2011). Algorithms widely used in determining life-affecting circumstances are often black-boxed; that is, they are opaque, 'invisible' and indiscernible for social and welfare recipients. 'Like gods, these mathematical models [are] opaque, their workings invisible to all but the highest priests in their domains: mathematicians and computer scientists' (O'Neil, 2016: 3). As Powles (2018) rightly argues, we need genuine accountability mechanisms, external to companies and accessible to populations.

In the Global South, the digital revolution shapes risks and opportunities concerning gender inequality regarding social and welfare systems. For example, the Gates Foundation has warned that digital technology, in particular mobile banking, could bypass millions of women in Africa (Wintour, 2019). On the other hand, Gelb, Mukherjee and Navis (2018), studying the digital governance Aadhaar platforms in the Krishna district of Andhra Pradesh (which allows the government to biometrically identify recipients of social services and subsidies including social pensions), found that women expressed stronger preferences relative to men for the consistency of digitally delivered benefits. They also appreciated the increased control over their benefits, increasing their agency over entitlements and subsidies. A study on mobile phone ownership and usage by women in India, using 2004-2005 National Family Health Survey cross-sectional data, found that households where women had mobile phones reported lower tolerance for domestic violence and higher women's autonomy in mobility and economic independence (Bhowmick, 2018).

As such, prioritising digital literacy for women by combining mobile technology with the array of existing welfare programmes targeted at women can potentially lead to similar empowerment of women in rural India. Pande and Schaner (2017) proposed the adoption of mobile phone-enabled check-ins for a conditional welfare programme, presenting the hypothetical example of a scholarship for girls that is received only by those who can verify their attendance at school via phoned-in check-ins. Integrating benefits targeted to the poorest women in the Global South in this manner could be a promising way to make welfare programmes fairer and more effective for women during the digital revolution. In these

ways, potential risks can be assuaged, and opportunities harnessed, to shape digital technology in ways that prevent harm and instead contribute to advancing gender equality and women's rights in the digital age.

Leveraging technology to advance gender equality: policy recommendations

Despite the range of initiatives that have been implemented in the past, there is a lack of coherent policy on promoting the participation of women in the digital revolution. Digital technologies may provide new opportunities for making progress, but 'tech fixes' can do little to address the underlying structural problems driving the digital gender divide. The focus needs to be on putting in place concrete policy actions fostering women's and girls' full participation and inclusion in the digital revolution, while at the same time addressing ingrained stereotypes, practices and norms that lead to discrimination and even violence against women (OECD, 2018). There is no one solution to closing gender digital divides and ensuring that digital technologies can be harnessed for women's empowerment. Gender digital inequality stems from multiple intersecting economic, social, political and cultural barriers, and remedies must be grounded in evidence about which barriers are in play across different contexts.

- Move away from techno-solutionism; that is, thinking that gender equality can be achieved through more automation and technologies. Gender analysis must be an integral part of technological investment, research and design.
- New (inter)national legal-institutional frameworks need to be put in place to protect and promote women's rights in the digital revolution.
- Compulsory education, particularly for women gaining digital skills in developing economies, is necessary. Raising awareness around educational opportunities can help to narrow the digital gender divide, and women must have the right to training, re-skilling and job transition pathways, especially in frontier fields such as data science and AI.
- Ethical auditing, monitoring and governance frameworks of AI technologies must be put in place. There is a need for increased transparency, and for national AI ethics councils to, for example, audit algorithms of new technologies that enter the market. New ethical codes for AI are needed, with gender equity a significant element of these codes; and there must be increased awareness regarding representation in the data sets, particularly in their collection and curation.
- Examine exclusionary practices and language, encourage men to become strong allies, and promote women STEM role models and mentors. Actively inspire women to become equal partners in technological design, development and implementation teams and practices.
- Incorporate gender mainstreaming into HR policy until women and men are given equal access to well-paid jobs and promotions. Actionable incentives, targets and quotas for recruiting, retaining and promoting women at work should be established. Promote decision-making spaces in the digital realm to be adequately gender balanced.

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