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Women in Cyber Security Literature Review

Department of the Prime Minister and Cabinet
Public Service Research Group & Australian Centre for Cyber Security

on behalf of UNSW Canberra for the Women in Cyber Security Careers Project
June, 2017



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Research
Group

Contact Details

Dr Sue Williamson

Senior Lecturer in Human Resource Management, Public Service Research Group

The University of New South Wales, Canberra ACT 2610

Phone: 0419 498 575

Email: s.williamson@adfa.edu.au

Alison Creagh CSC

Industry Fellow, Australian Centre for Cyber Security

The University of New South Wales, Canberra ACT 2610

Phone: 0408 585 890

Email: alison.creagh@adfa.edu.au

Mika Tranter

Research Administrator, Public Service Research Group

The University of New South Wales, Canberra ACT 2610

Phone: 02 6268 8074

Email: m.tranter@adfa.edu.au

This report was authored by: Meraiah Foley, Linda Dewey, Sue Williamson, Deborah Blackman, Alison Creagh, Lisa Davidson, Meng Zhu and Jill Slay.

Executive Summary

The Department of Prime Minister and Cabinet (PM&C) has conducted exploratory research into women's low representation in the cyber security industry, and found that marketing, role models, and hiring practices are barriers to attracting women into the industry. Further, these initial findings also include that workplace culture, a lack of flexible working arrangements, and persistent discrimination impede women's retention in the industry (Department of Prime Minister and Cabinet, 2017).

This report examines the existing limited research on women in the cyber security industry, and women in science, technology, mathematics, and engineering (STEM) and information and communication technology (ICT) to identify barriers to women's labour market participation. Overall, PM&C's initial findings hold. While limited research exists on women's participation in cyber security, findings from the burgeoning and ever-increasing STEM and ICT literature provide useful indicators of barriers to women in cyber security, revealing a complex and multi-layered picture, replete with persistent and enduring barriers. Barriers to girls and women commence early – from primary school – and continue throughout women's careers to the executive levels. Barriers also exist at all stages of the employment life cycle, from recruitment to career development and performance management, culminating in women leaving the industry.

Female employees are vastly under-represented in cyber security, constituting only 11 per cent of the global information security workforce and 10 per cent of the Asia-Pacific workforce (Reed et al., 2017). Of the 11 per cent of positions held by women in the global cyber security workforce, more than half of those positions are entry-level or non-managerial positions. In the Asia-Pacific region, women hold no C-level positions, and account for 1 per cent of executive management roles (Reed et al., 2017, p. 9). A major global survey has found that women in the cyber security industry experience widespread discrimination, persistent occupational segregation, and wage inequality (Reed et al., 2017).

In Australia, specific practices and policies that have been found to exclude, marginalise, or disadvantage women in the STEM and ICT fields include: long hours working cultures, women professionals being excluded from the "boys' club", women being subjected to sexist remarks, and the technical expertise of women being regarded less seriously than that of male colleagues. Of those considering leaving their current employer, occupation or industry, 24.2 per cent said culture was a major factor (Professionals Australia, 2015). Women also leave the sector because of a lack of flexible working arrangements, a lack of career development and progression and widespread discrimination (Hewlett, et al, 2008; 2014; Hill, et al, 2010; Reed et al, 2017, p. 13).

Key Findings

- ♦ Women represent just 11 per cent of the cyber security workforce globally, and 10 per cent in the Asia-Pacific, where women hold no C-level cyber security positions just 1 per cent of executive management roles (Reed et al., 2017).
- ♦ There is little information about the gender composition of the cyber security workforce in Australia. However, women are poorly represented in cyber security's traditional feeder fields, such as STEM and ICT (Prinsley et al., 2016).
- ♦ Women in cyber security report widespread discrimination and stereotype bias. Fifty-one per cent of women in cyber security have experienced some form of direct or indirect discrimination, compared to 15 per cent of men (Reed et al., 2017).
- ♦ The "24x7" work culture of cyber security is a significant barrier for many women, particularly workers with families or caregiving responsibilities (Bagchi-Sen et al., 2010). Lack of part-time or flexible hours is a primary cause of women's attrition from STEM and ICT (Hewlett, et al, 2008; 2014; Hill, et al, 2010).
- ♦ More than a quarter of women in cyber security perceive that their opinions are not valued by their employers. Those who do feel valued are more likely to work for organisations that provide mentoring and sponsorship (Reed et al., 2017). Perceptions of stalled or stagnant careers are a major contributor to women's attrition from STEM and ICT careers (Hewlett et al., 2008, 2014).
- ♦ Women in cyber security face persistent wage inequality (Reed et al., 2017). Studies of the gender pay gap in STEM and ICT find that wage inequality in technical careers cannot not explained by motherhood or part-time employment (Baranyai et al., 2016).
- ♦ Women's attrition from STEM and ICT in Australia begins in primary school, where differences in girls' perceived self-efficacy in these subjects have been linked to poorer performance and subject engagement (Buckley, 2016).
- ♦ At the university level, women account for only one in four ICT graduates, a proportion that has been steadily declining since 2001 (Department of Employment, 2017).

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1. Introduction

Female employees are vastly under-represented in cyber security, constituting only 11 per cent of the global information security workforce (Frost & Sullivan, 2017). Exploratory research suggests that marketing, role models, and hiring practices are barriers to attracting women into the industry, and that workplace culture, a lack of flexible working arrangements and fear of failure impede women's retention in the industry (Department of Prime Minister and Cabinet, unpublished). This report examines existing academic and industry literature to identify the barriers to women entering and staying in the cyber security industry.

The report commences with an overview of women in cyber security globally, and in Australia, highlighting the low representation of women and existing known barriers. A brief history of women in ICT is then presented, revealing that women have not always been underrepresented in this industry, but that the rate of women entering the industry has plummeted over the last thirty years. The report then examines the gender gap for women in STEM and ICT, finding that the "leaky pipeline" commences in primary school and continues throughout a woman's career. Occupational segregation is a major feature of women in STEM and ICT, a phenomenon which is explored, followed by a detailed examination of why women leave the sector. A theoretical explanation of how organisations are gendered and how this may be overcome is contained in the Appendix, aiding understanding of the wide-scale societal dimensions of gender inequity in organisations.

Reasons why women are needed in the cyber security industry are presented, followed by a review of the research which has examined strategies which have been successfully used to increase women's representation in other industries, including those which are male-dominated. The methodology used for the report is also detailed. The report then concludes, with the authors recommending further research be conducted to determine whether identified strategies would be applicable to the cyber industry.

2. Women in cyber security: The global perspective

Female employees are vastly under-represented in cyber security, constituting only 11 per cent of the global cyber security workforce and 10 per cent of the Asia-Pacific workforce (Reed et al., 2017). According to the 2017 Global Information Security Workforce Survey (GISWS) which polled 19,641 information security professionals in 170 countries, women in the industry experience widespread discrimination, persistent occupational segregation, and wage inequality. Despite public and private sector efforts to attract women to these positions, the proportion of women in cyber security has barely budged since the last GISWS survey in 2013. This stagnation is notable, as the gap between qualified security

professionals and unfilled positions is estimated to reach 1.8 million by 2022 (Reed et al., 2017, p. 7).

The specific causes of women's underrepresentation in the cyber security field are still largely unknown. However, the GISWS, the largest survey of its kind, suggests a strongly gendered environment. Although women enter the cyber security profession with higher education levels than men, they are substantially underrepresented at the most senior levels of the industry. Globally, men are four times more likely to hold C-level positions, four times more likely to occupy executive management positions, and nine times more likely to hold managerial positions than women (Reed et al., 2017, p. 7-8). Of the 11 per cent of positions held by women in the global cyber security workforce, more than half of those positions are entry-level or non-managerial positions. In the Asia-Pacific region, women hold no C-level positions, and account for 1 per cent of executive management roles (Reed et al., 2017, p. 9).

Women in the industry also report high levels of discrimination. Fifty one per cent of women working in the global cyber security space have experienced some form of discrimination. The most common forms of discrimination include perceptions of unconscious bias, at 87 per cent; unexplained denials or delays in career advancement, at 53 per cent; and having errors pointed out in exaggerated fashion, at 29 per cent. Twenty-two per cent of women reported feelings of tokenism, and 19 per cent experienced overt displays of discrimination. Perceptions of discrimination increase as women rise up the ranks, with 67 per cent of women in C-level positions reporting experiences of discrimination, compared to 50 per cent of non-managerial and 35 per cent of entry-level staff. These results suggest that unlawful discrimination in the industry is widespread; raising questions about whether bias and prejudice are a key cause of women's poor representation in cyber security. To date, the academic literature examining women's experiences in cyber security is relatively limited. Findings from related fields, such as the historically male-dominated domains of science, technology, mathematics, and engineering (STEM), and information, communications, and technology (ICT) suggest that gender biases in these fields manifest as early as primary school (Thomson et al., 2012), contributing to women's attrition from these fields at nearly every stage in the pipeline, from primary school to the C-suite.

Women in cyber security face persistent wage inequality, particularly at the lower job classifications, where women are primarily concentrated. According to the GISWS, women earn, on average, 3 per cent less than men in equivalent roles at the director level; 4 per cent less than men at the managerial level; and 6 per cent less than men in non-managerial and entry-level roles (Reed et al., 2017, p. 12). More than a quarter of women surveyed (28 per cent) indicated that their opinions were not valued in their organisations. Women who did feel valued in their positions, however, were significantly more likely to report that their organisation provided adequate training, mentorship, development, and leadership programs (Reed et al., 2017, p. 15).

3. Women in cyber security: The Australian perspective

Like the rest of the world, Australia also faces a growing shortfall of cyber security professionals to build the nation's capacity to protect itself from cybercrime, espionage, and cyberattacks (Department of the Prime Minister and Cabinet, 2017; Australian Cyber Security Centre, 2015). The Australian Signals Directorate (ASD) has reported that cyber security incidents involving both the Australian Government and other networks of national interest increased by more than 260 per cent from 2011, with 313 incidents reported, to 1,131 incidents reported in 2014 (Australian Cyber Security Centre, 2015). The Washington-based Center for Strategic and International Studies (CSIS) forecasts that the cyber security market in Australia will grow to \$1.6 billion dollars by 2019 (CSIS, 2016, p. 10).

There is little public information about the gender composition of the cyber security workforce in Australia, which spans various employment classifications, including the financial and insurance services; the professional, scientific, and technical services sector; and the information, communications, and technology (ICT) sector, among others. In ICT, where many information security positions are traditionally clustered, women are chronically underrepresented. Although women comprise 46 per cent of all employees in Australia, they hold only 28 per cent of ICT jobs (WGEA, 2016), and are concentrated in lower-level administrative and logistical support positions (Australian Computer Society, 2015).

Although the exact number of women in the cyber security field in Australia is unknown, it is well established that women are severely underrepresented in cyber security feeder fields, such as STEM and ICT (Prinsley et al., 2016). The process of attrition from these fields begins as early as primary school, if not earlier, and continues through tertiary education. To boost the pool of women graduates in these fields, the Australian Government established the National Innovation and Science Agenda, investing \$13 million over five years from 2016-17 to encourage young women to pursue careers in STEM-related fields (Australian Government, 2015). At present, women account for only one in four ICT graduates, a proportion that has been in steady decline since the early 2000s, and fewer than one in 10 engineering graduates in Australia (Department of Employment, 2017). By some estimates however, 75 per cent of the fastest growing occupational categories belong to the STEM sectors (Department of Employment, 2017). The lack of women with qualifications in these fields means not only that women risk missing out on opportunities to benefit from lucrative, cutting edge jobs that do not yet exist, but employers also face a reduced applicant pool, and will not reap the benefits of a truly diverse and representative workforce.

4. Women in STEM and ICT: Attrition through the pipeline

Due to the fragmented nature of the cyber security workforce, and the relative newness of the sector, there is very little academic research examining women's engagement with cyber security, both globally and in Australia. However, the literature on women's engagement with STEM is expansive, as is the literature on women's engagement with ICT. As both STEM and ICT are traditional feeder fields to cyber security, this body of research provides valuable insights about the gender gap in the cyber security workforce. This section examines the global and Australian literature on women in STEM and ICT, focusing on the historical trends of women's participation in computer science, the educational pipeline in STEM and ICT, and the challenges faced by women working in these industries. At every level, the story of women in these fields is one of attrition, owing to a complex range of socio-cultural factors (Prinsley et al., 2016).

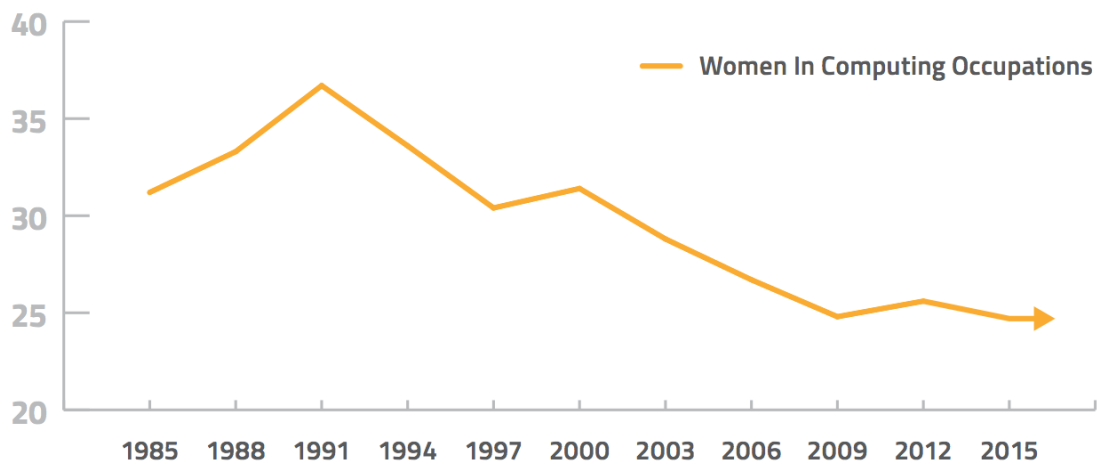
4.1 The rise and fall of women in ICT

The lack of women in ICT jobs today is well known; but this was not always the case. In the early decades of computing history, programming was so female dominated, it was seen to be a "pink collared profession" (Cole, 2014). During World War II, women famously played a key role in the breaking of codes and deciphering of messages passed by the Germans and the Japanese (Wilcox, 1998). Of the 10,000-plus employees at the Government Code and Cypher School at Bletchley Park, two-thirds were women (Heath, n.d.). Through the 1940s, computer programming continued to be classified as largely as clerical work, one of the few employment options available to women at that time (Light, 1999). By the 1970s, however, perceptions of computer programming began to shift from low-level clerical work to a more highly skilled, challenging, and well-remunerated profession requiring knowledge of logic, mathematics, and electronic circuits (Light, 1999). Although programming continued to be an important source of employment for women, men's increasing entry into the field and sexual divisions of labour at home saw women concentrated in the lower echelons of the computer hierarchy (Green, 1993).

Women's marginalisation in the industry continued into the mid-1980s, which saw the advent of the first personal computers. Early home computers, such as the Commodore 64 and the Apple Macintosh, were marketed mainly as gaming devices for boys and men, meaning families were more likely to purchase computers for boys rather than girls, giving boys an early head start in the burgeoning computer sciences field (Margolis and Fisher, 2002). This connection of computers with boys aligns with the development of the "geek" and "nerd" culture in computing (Henn, 2014). According to Justine Cassell, director of Northwestern University's Centre for Technology & Social Behaviour, this stereotype drove girls further from the profession because "girls and young women don't want to be that person" (Stross, 2008). Since the 1980s, the number of women pursuing computer sciences degrees has been in near-steady decline in Australia and the United States, with a concomitant decline in women's participation in the information technology workforce. Figure 1 illustrates how this trend has played out in the United States, where the percentage

of computing occupations held by women has been declining since 1991, when it reached a high of 36 per cent (U.S. Bureau of Labor, 2016, in Ashcraft et al., 2016, p. 7).

Figure 1. Proportion of computing occupations held by women, 1985-2015, United States



Source: U.S. Bureau of Labor, 2016, in Ashcraft et al., 2016, p. 7

This downward trend has prompted volumes of research examining where women are lost in the pipeline, from school to professional engagement. This is examined in the next section.

4.2 The “leaky pipeline”: The gender gap starts at school

The cumulative attrition of women from the STEM and ICT fields has proven persistent and difficult to mend (see, for example, Bell and Yates, 2015). Like many other industrialised countries, Australia loses female talent at every stage of the educational pipeline, despite increasing consensus in neuroscience that there is no fundamental cognitive ability gap between men and women when it comes to science and mathematics, the gateway to many STEM careers (for a discussion, see Buckley, 2016).

4.2.1 Primary and secondary school

The gender gap in technical fields begins early. Differences in both engagement and self-efficacy with mathematics appear on the earliest standardised tests in Australia. Girls and boys in Year 3, for example, had similar average performance scores in mathematics on the 2015 round of the National Assessment Program in Literacy and Numeracy (NAPLAN), but only 12 per cent of girls achieved at the highest level, compared to 15.7 per cent of boys. In Year 5, 7.7 per cent of girls scored in the highest band, compared to 11.5 per cent of boys (Prinsley et al., 2016). One popular explanation for the small number of women in these fields is the belief that women are inherently less capable than men, or biologically predisposed to non-STEM disciplines (see for example, Kenny, 2014). If this were so, however, gender differences would be consistently observable across countries, over time. Instead, the gender gap in mathematics varies from country to country, and has been

shown to rise and fall with different pedagogical approaches (Prinsley et al., 2016). A meta-analysis of more than 240 studies published between 1990 and 2007 found no statistically significant gender difference in mathematics performance (Lindberg et al., 2010).

In Australia, standardised tests show that the gender gap is not constant, but widening. Australian results on the Programme for International Student Assessment (PISA), the international benchmarking test for maths, science and literacy run by the Organisation for Economic Cooperation and Development (OECD), have deteriorated sharply since 2003, when girls' performance was similar to boys' (Thomas et al., 2013). This is echoed by another study examining enrolments in the New South Wales High School Certificate (HSC) over 2001 to 2011, which found that the number of male and female students choosing to complete at least one maths and at least one science subject had decreased but the decline was steeper for girls than for boys (a 3 per cent decline, compared to 1.1 per cent) (Wilson and Mack, 2014). In contrast, Singapore, one of the world's top performing countries in maths and science, has nearly closed the gender gap in both performance and perceived self-efficacy in these subjects through a targeted maths curriculum and heavy investments in pedagogical training, illustrating that girls can and do excel in these subjects given the right educational environment (OECD, 2014).

Researchers concerned about this growing gender gap have turned their attention to the influence of cultural beliefs and attitudes on student performance (Nagy et al., 2010; Spelke, 2005; Watt et al., 2012), particularly the influence of social factors (such as the influence of parents and peers) on students' interest, sense of competence, and emotional engagement with a subject. Self-efficacy beliefs are strong predictors of vocational interests and the pursuit of career options (Michie and Nelson, 2006). These expectations are developed early in childhood and are influenced by parents and teachers who inadvertently reward or reinforce certain childhood behaviours along gendered lines. One study from the United States, for example, found that girls aged five to seven performed worse on a mathematics test if their mothers endorsed negative gender stereotypes about mathematics (Tomasetto, et al., 2011). Cultural beliefs around gender roles and the gender-appropriateness of certain fields of study or career activities are strong predictors of perceived self-efficacy among men and women; and computer-related activities are found to fall firmly on the masculine side of the gender divide (Margolis et al., 1999).

Motivational beliefs, including personal attitudes about the value of mathematics, as well as perceptions of self-efficacy, are powerful forces that may account for a substantial degree of the gender gap in achievement and engagement with mathematics (Newcombe et al., 2009). On average, girls have less confidence and more anxiety regarding mathematics. In Australia, only 33 per cent of girls see themselves as confident in their maths abilities, compared to 42 per cent of boys (Thomson et al., 2013). Girls also experience higher rates of maths-related anxiety than boys (Thomson et al., 2013), which is associated with poorer mathematics achievement (Carey et al., 2016). The extent to which students perceive

intrinsic value in a subject, such as maths, is also predictive of whether secondary school students see it as a potential career pathway (Buckley, 2016).

Low levels of intrinsic value are associated with lower rates of participation in advanced mathematics study, the foundation for a career in computer science (Roberts, 2014). Longitudinal research shows that Australian girls have significantly lower levels of intrinsic value for mathematics than Australian boys. For example, one-third of 15-year-old girls believe mathematics is not important to their future careers, compared to 20 per cent of boys (Thomson et al., 2013); by year 12, boys outnumber girls in advanced mathematics courses by a ratio of nearly 2:1 (Kennedy et al., 2014). The gap in mathematics self-efficacy scores between girls and boys was wider for Australian students than for students in Singapore, Canada, and the United States (Thomson et al., 2013). These findings suggest that Australian girls are less likely to engage with mathematics, less likely to choose career pathways that involve mathematics, and more likely to be outperformed by their male peers (Buckley, 2016). This has substantial downstream effects for women's participation in STEM and ICT fields, including cyber security.

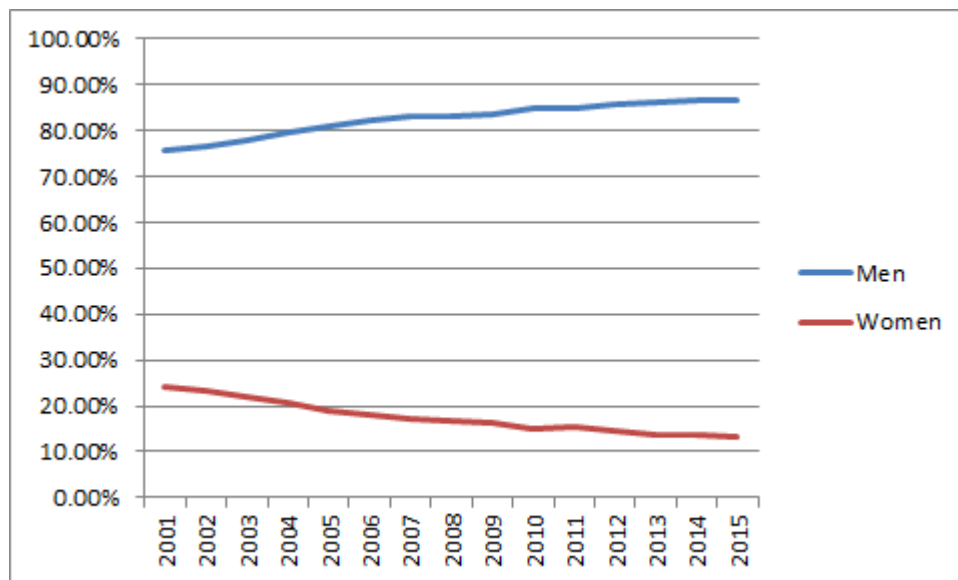
4.2.2 Tertiary education and beyond

The poor representation of women in STEM and ICT continues into university. Women accounted for 65 per cent of domestic graduates across all subjects in 2015, but only 33 per cent of graduates in mathematics and 13 per cent in ICT fields (Prinsley et al., 2016, p. 2), a proportion that has been falling steadily over the past two decades. Women and men have been shown to perform equally well in computer science courses at the university level (Beyer, 2014), yet women continue to leave the field at rates that are not correlated with lower grades or poorer performance on standardised mathematics tests (Tam and Bassett, 2006 in Beyer, 2014). Female students in these fields have few role models among teaching and research staff at Australian universities. In 2014, women accounted for just 28 per cent of academic and research staff at any level (Prinsley et al., 2016).

This was not always the case. The proportion of women achieving bachelor's degrees in computer science in the United States grew steadily from the mid-1960s until the early 1980s, when the widespread use of home computers became commonplace. According to the National Centre for Education Statistics (NCES), women in 1966 accounted for about 15 per cent of computer science students in the United States, and 37 per cent of undergraduate computer science students in 1983-84 (NCES, n.d.) Since that time, the proportion of women enrolled in these degrees been in steady decline. In 2010-11, women accounted for just 17.6 per cent of computer science students (NCES, n.d.). The proportion of women pursuing bachelor's degrees in computer science fell by 20 per cent from 2000 to 2005, and dropped a further 22 per cent from 2005 to 2010.

Australian data tells a similar story. The proportion of domestic women undergraduate students enrolled in ICT courses in Australia fell from 24 per cent in 2001, the end of the dot com boom, to 13.5 per cent in 2015 (Department of Education and Training, n.d.). The share of men in these courses increased from 77 per cent to 87 per cent in the same timeframe, as shown in Figure 2, below.

Figure 2. Undergraduate enrolments in ICT degrees, 2001-2014, Australia



Source: Department of Education and Training, n.d.

Stereotypes and popular perceptions that women are less suited to some subjects have also been found to contribute to the gender gap in ICT feeder fields, such as mathematics. A study of university students from the United States found that female university students were more likely to disengage with mathematics if they believed that their ability in the subject was determined by sex, and was therefore immutable (Burkley et al., 2010). Female university students were also found to have a lower sense of belonging in mathematics if they perceived that their university supported or encouraged stereotypes about women's cognitive abilities (such as the view that women are not as good at calculus as men), or perpetuated the notion that mathematics ability is predetermined by biological sex (Good et al., 2012).

These messages, which begin in primary school and compound through university, inhibit women's entry into information technology and computer science related fields (Michie and Nelson, 2006), which have long been described as "chilly climates" for women (Wright, 1997). Another barrier for women is the stereotypically masculine "geek culture" or "hacker culture" that is perceived to be endemic to many ICT fields. One study found that male and female students hold stereotypical views about computer scientists; namely, that ICT professionals are Caucasian, male, antisocial, and singularly focused on computers (Weingarten and Garcia, 2015). Women are less likely to see computer science as a viable

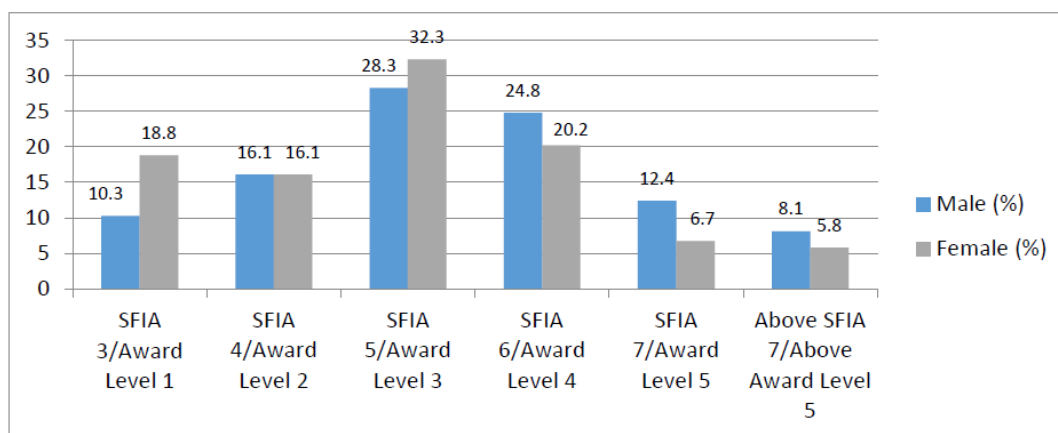
career path because they cannot see themselves in the stereotype (Cheryan et al., 2013). This reproduces male domination at every stage in the pipeline (Ahuja, 2002).

4.3 Professional segregation in the STEM and ICT sectors

The STEM and ICT sectors in Australia are characterised by high levels of gender segregation, both horizontal and vertical. Horizontal segregation is characterised by the under-representation of women in the sector. Within ICT, women account for just 28 per cent of all roles, and are largely concentrated in lower-level administrative or logistical positions (WGEA 2016). Vertical segregation is characterised by imbalances in leadership and pay between men and women *within* an industry or organisational hierarchy (WGEA, 2017d, p. 22). Horizontal segregation begins with education’s “leaky pipeline” and persists into the professional sphere. Women account for 33 per cent of tertiary qualifications in STEM fields in Australia (Roberts, 2014); but hold just 28 per cent of tertiary-qualified jobs in the STEM sector. Within the ICT sector, women account for just 25 per cent of the tertiary-qualified workforce, even though they hold 55 per cent of tertiary-qualified roles across all other sectors (Baranyai et al., 2016).

Within ICT and STEM, there is also evidence of vertical segregation, characterised by poor representation of women in senior management roles and persistent gender pay gaps across most levels. According to a 2015 remuneration survey undertaken by the Australian Computer Society (ACS), the peak body for ICT professionals, and Professionals Australia, an industry body representing more than 20,000 STEM professionals, women in technology are significantly overrepresented in the lower rungs of the industry’s professional classifications (Skills Framework for the Information Age), and wage classifications (known as Award Levels). The survey also found that average incomes were higher for males than females at all levels of responsibility, although the gap narrowed at the most senior level (Professionals Australia, 2017, p. 17).

Figure 3. ICT Professionals, levels of responsibility, by gender, Australia



Source: Professionals Australia, 2017, p. 18

Data from the Department of Employment shows that the number of women working in ICT occupations rose in the two decades to 2016, but the number of men working in the same occupations has generally risen faster. This means that in many roles within the sector, women have a smaller share, or percentage, of overall employment than they did 20 years ago, as shown in Table 1, below (Department of Employment, 2017).

Table 1. Female employment share and growth in ICT occupations, 1996-2016, Australia

Occupations	Female employment share (%)		Female employment growth (1996-2016)	Female employment level (2016)	Total employment level (2016)
	1996	2016	('000)	('000)	('000)
Software and applications programmers	19.9	18.7	8.1	18.1	97.1
ICT managers	12.9	20.5	9.4	10.8	52.8
ICT support technicians	50.0	21.4	-1.5	11.1	52.0
Graphic and Web Designers, and Illustrators	45.9	44.8	14.1	23.2	51.8
Database and Systems Administrators, and ICT Security Specialists	19.8	21.1	4.9	8.7	41.0
Electronics Trades Workers	6.1	4.2	-0.5	1.3	30.4
ICT Business and Systems Analysts	19.8	25.1	3.5	6.5	25.8
Telecommunications Trades Workers	2.4	4.0	0.2	0.9	23.3
Computer Network Professionals	18.8	14.7	0.9	3.4	22.9
ICT Sales Assistants	69.0	38.4	-2.4	6.8	17.8

Source: ABS (November 2016) *Labour Force, Australia, Detailed, Quarterly*, cat. no. 6291.0.55.003, four quarter average of original data, in *Department of Employment, 2017*, p. 29

Another survey undertaken by Professionals Australia in 2015 examined the experiences of 432 female professionals working in STEM. It found that the greatest contributors to vertical segregation were: difficulty balancing work/life responsibilities (28.3 per cent); workplace culture (28.2 per cent); lack of access to senior roles for women (26.9 per cent); and lack of women in senior roles, as exemplars or role-models (23.9 per cent). The survey found that 40.2 per cent of women do not believe they receive equal compensation for work of equal value compared to their male colleagues, and do not receive the same level of career training and development (33 per cent) (Professionals Australia, 2015). These factors are discussed further in the section on “Professional attrition: Why women leave STEM and ICT”.

4.4 The gender pay gap in STEM and ICT

In Australia in 2015/16, the full-time gender pay gap across all sectors was 16 per cent. However, in the two sub-classifications where most ICT and cyber security roles reside (i.e. professional, scientific, and technical services and information, media, and communications) the gender pay gap was 25.4 per cent and 18.5 per cent respectively (WGEA, 2017c).

A recent survey of women in STEM fields also reveals a significant pay gap. Among tertiary-qualified STEM graduates, 32 per cent of men achieve the highest income bracket, earning more than \$104,000 per annum, compared with just 12 per cent of women (Baranyai et al., 2016). Although motherhood and part-time employment exert a negative effect on women’s earnings, the effect of gender alone appears to be more significant. Among STEM graduates with an undergraduate bachelor degree over age 30 (the prime child-rearing years for tertiary graduates), 18.6 per cent of women without children are in the top income bracket, compared with 11.6 per cent of women with children, and 35.4 per cent of men (Baranyai et al., 2016). Among PhD holders over age 30, 20.7 per cent of women without children earn more than \$104,000 per annum, compared with 19.4 per cent of women with children, and 38.6 per cent of men. The effect of motherhood cannot explain why nearly twice as many men end up in the top income bracket in STEM fields (Baranyai et al., 2016).

As with other industries, women in STEM are significantly more likely than men to work part-time, with 13.1 per cent employed on a part-time basis compared to 3.9 per cent. This results in lower overall female wages. However, the gender pay gap persists, even when controlled for the effects of part-time work. For example, tertiary-qualified men who work part-time in the STEM sector are up to four times more likely to be in the top income bracket (earning more than \$104,000 per annum) than equally qualified women who also work part-time (Baranyai et al., 2016, p. 55).

4.5 Professional attrition: Why women leave STEM and ICT

In the professional sphere, women exit the STEM and ICT sectors in large numbers. Attrition rates for women from STEM are reported to be anywhere from 50 to 90 per cent at the early to mid-stages of their careers (Snyder, 2014). For example, Hewlett et al. (2008; 2014) have examined the experiences of women in STEM in dozens of international companies around the world, including Australia. They find that women’s primary reasons for leaving

include: hostile work cultures; isolation from mentors and sponsors; unclear career paths, and extreme work pressures. These findings are echoed by the 2016 Elephant in the Valley¹ survey, which polled 210 female professionals working in Silicon Valley about the challenges of being a woman in ICT. According to that survey, 66 per cent of women said they felt excluded from key social or networking opportunities because of gender and 59 per cent were not given the same career progression or development opportunities as their male colleagues. Discrimination was another significant challenge, with large proportions of women reporting sexist behaviour, both in their organisations and at industry conferences. While these are challenges experienced by women in many industries, the findings suggest a more strongly gendered environment in the ICT sector, which may contribute to women's poor levels of representation and high rates of exit from the field.

In Australia, specific practices and policies that have been found to exclude, marginalise, or disadvantage women in the STEM and ICT fields include: long hours working cultures, women professionals being excluded from the “boys’ club”; women being subjected to sexist remarks; and the technical expertise of women being regarded less seriously than that of their male colleagues. More than half of the respondents to the Professionals Australia survey, or 54.2 per cent, said that workplace culture had detrimentally impeded their career advancement to a significant or moderate extent. Of those considering leaving their current employer, occupation or industry, 24.2 per cent said culture was a major factor (Professionals Australia, 2015).

4.5.1 Inflexible workplaces

Women consistently cite the lack of part-time or flexible hours as one of the reasons they leave careers in STEM and ICT (Hewlett, et al, 2008; 2014; Hill, et al, 2010). Many women in STEM perceive strong biases against part-time workers. Two-thirds of respondents to the Professionals Australia survey on gender in STEM agreed or strongly agreed that promotions in their workplaces are generally drawn from the pool of full-time employees, and that part-time workers are not afforded the same level of mentoring or training opportunities as full-time workers (Professionals Australia, 2017, p. 15). The survey found that even where employers provided family-friendly work policies, cultural issues within workplaces meant that accessing these provisions was difficult or discouraged. For example, 44.4 per cent of respondents disagreed or strongly disagreed with the statement that managers and senior leaders in their organisations modelled good work/life balance; 41.8 per cent said their employer had good work/life policies but the culture of the organisation did not support it. These effects were compounded for employees with caring responsibilities. Seventy per cent of respondents said that taking maternity/parental leave was detrimental to their careers; and 21.3 per cent said they had been sidelined for promotion because they had taken a career break (Professionals Australia, 2015).

Similarly, 75 per cent of respondents to the Elephant in the Valley survey reported that they were asked about family life, marital status, and children in job interviews. Forty per cent

¹ <https://www.elephantinthevalley.com>

said they felt compelled to speak less often about their family life to be taken more seriously. Among women who had taken maternity leave, 52 per cent shorted their leave because they worried it would impact negatively on their careers. A recent mixed methods study of cyber security professionals in the United States highlights similar themes. For many women, the “be ready for 24 x 7” culture of the cyber security industry (Bagchi-Sen et al., 2010, p. 28) was a significant barrier, particularly those with families or caregiving responsibilities.

Volumes of research show that traditional concepts of career advancement, which value a full-time, uninterrupted, ‘linear’ career trajectory disadvantage women, who are more likely than men to work part-time or take career breaks to accommodate family or caregiving responsibilities (Skinner and Pocock, 2014; Baird, 2004). These issues are present in most industries and workplaces in Australia. However, given the gendered inequalities present in the educational pipeline, and the already small pool of female candidates for the STEM and ICT workforce, which includes and cyber security, the implications of these findings are particularly serious (Senate Finance and Public Administration Committees, 2017).

4.5.2 Career stagnation and progression blockages

The 2017 GISWS (Reed et al., 2017) found that 28 per cent of women in the industry feel that their opinions are not valued. Those who *did* feel valued were more likely to indicate that their organisation provided adequate training and leadership development opportunities, at a margin of 61 per cent to 47 per cent who felt undervalued and did not feel that their organisations had adequate training or development opportunities (Reed et al., 2017, p. 15). Similarly, women in cyber security have been shown to face difficulty building and belonging to networks for like-minded peers. Without these networks, some women struggle to establish trust, understand the “political landmines” in their corporate settings, and to confront or challenge a senior professional who may be about to make, or is clearly making, a wrong or ill-advised decision (Bagchi-Sen et al., 2010, p. 28).

Within the wider STEM and ICT fields, a significant number of women in the STEM and ICT fields feel “stalled” or “stuck” in their careers (Hewlett et al., 2008). In one recent survey, 80 per cent of female STEM professionals said they “loved” their work, but 32 per cent also said they were likely to leave their jobs within a year due to a lack of progression (Hewlett et al., 2014). Women report being confused as to what a career path may look like in their organisation, as there is little transparency around career paths, development, and progression (Hewlett, 2008, p 21). Women in these fields report that male colleagues are more likely to be “tapped on the shoulder” for development opportunities or senior positions (Hewlett et al., 2008, p 24). Eighty-three per cent of the participants identified that they had never had the support of a sponsor within their organisation, and that they believed this support would assist their careers (Hewlett et al., 2008, p 23). Sponsorship is defined as a relationship with a superior that extends beyond mentorship (Reed et al., 2017, p. 15).

Several studies (e.g. Ashcraft et al., 2016; Hewlett, 2014; Hunt, 2010; Hewlett, 2008) cite isolation and lack of mentorship or sponsorship as one of the key barriers to the retention

of women in STEM and ICT, particularly for women seeking to pursue senior and leadership roles (Nash, 2016). Warren (2009) evaluated the talent and performance management systems of some 110 corporations covering 19 industries across the US through a series of interviews and surveys and identified that the narrow image of what senior talent looks like, and the shortfall of experienced talent at senior levels is resulting in gender-biased systems that negatively affect the careers of women. Senior leaders, primarily males, set the tone, and the stereotypes they hold reflect through the whole system as the human resource managers translate this tone into policies and procedures that are used by managers and employees as very few organisations implement checks and balances to reduce or eliminate biases and to level the playing field (Warren, 2009, p. 6). The result of this process is the compounding of bias as new leaders mirror the traits and biases of those who promote them.

4.5.3 Bias, harassment, and discrimination

Within cyber security, perceptions of gender stereotypes and biases are widespread. Globally, 51 per cent of women working in cyber security report experiencing workplace discrimination, compared to 15 per cent of men. Among women who have experienced discrimination, 87 per cent perceived that the discrimination was not overt, but based on unconscious or implicit stereotypes about women being less capable or competent in the technical domain (Reed et al., 2017, p. 13).

The Elephant in the Valley survey also revealed strong perceptions of discrimination in the ICT sector. An overwhelming proportion of women reported witnessing sexist behaviour at company off-sites and/or industry conferences (90 per cent). Similarly large proportions experienced clients or colleagues addressing questions to male peers that should have been addressed to them (88 per cent), and demeaning comments from male colleagues (87 per cent). Social psychologists argue that it is difficult for women in male-dominated roles, such as STEM and ICT fields, to strike the right tonal balance between feminine and masculine without being seen as too meek or too harsh. Women in these fields are also significantly more likely to receive feedback that their communication styles are aggressive, and to receive personality criticism in their performance reviews (Simard et al. 2008). This is because of the incongruity between the normative roles women are expected to fill and the stereotypical assumptions about what makes a good “techie” or a “strong” leader (Eagly and Karau, 2002; Ridgeway, 2011).

Within STEM more broadly, women describe the culture of these industries as “hostile” and “macho”, in which the “geeks” and “fire fighters” are rewarded for their behaviour, which is modelled from the top down (Hewlett et al., 2008, p 7). Others argue that the notion of ICT as an industry of “young, white guys who eat, breathe and sleep coding” or “basement dwelling, hoodie clad guys” is a misconception (Weingarten and Garcia, 2015, p 1), as many typical jobs do not involve programming. However the “geek” and “nerd” stereotypes persist, as do stereotypes about women being less competent in STEM subjects (Hill et al., 2010) and less competent in the cyber security domain (Weingarten and Garcia, 2015, p 3).

5. The business case for gender equality in cyber security

The business case for increasing the proportions of women in paid employment has been well established. The business case for gender equality resides within a managing diversity approach, based on human capital theory: “an advocacy of the benefits of finding a profitable or practical use for a diverse range of people and their skills, representative of society” (Burgess et al., 2009, p. 81). Researchers have argued that increasing and retaining women in the workforce can lead to increased productivity and gaining a competitive advantage, through fully utilising all employees’ skills (Burgess et al., 2009, p. 81).

Women, on average, are also more highly educated than men, but have lower workforce participation (WGEA, 2016). As such, they represent a significant untapped talent pool. In Australia, 20 per cent more women aged 25-35 hold bachelors’ degrees than do men (WGEA, 2013, p. 2). Globally, women also hold more advanced degrees (Suby, 2015, p. 9). Research has shown that organisations that value diversity are better able to retain staff (WGEA, 2013, p. 3). Furthermore, women who leave an organisation to work for another firm become potential competitors, poaching clients and staff (Loehr, 2015). Organisational performance can also be enhanced through improved decision-making, which can result in positive financial outcomes (WGEA, 2013; Kossek et al., 2006). Increasing diversity by employing more women can also increase an organisation’s revenue through ‘mirroring’ the customer base, thus attracting and increasing customers (Kossek et al., 2006). Women controlled some 64 per cent of household spending in 2013, which equates to around US\$30 trillion – that proportion is estimated to increase by a up to one-third by 2018 (World Economic Forum, 2016). It makes good business sense to have employees who better understand how to target that market.

Women also provide a gender diversity for cyber security that improves performance (Loehr, 2015) as a diverse workforce is more likely to experiment, be creative and more effectively complete tasks (Percival, 2016). The low proportion of women in the field represents a lost opportunity to harness the perspectives and experiences of women in developing new solutions and approaches. True innovation requires creativity, flexibility, and out-of-the-box thinking, which may be stimulated by diversity (Mannix and Neale, 2005). Indeed, recent findings suggest that diversity is good for business; and is strongly associated with higher business revenue and profits (Herring, 2009).

Organisational reputation can also be enhanced, particularly if the organisation becomes an employer of choice for women (WGEA, 2013, 7; Kossek et al., 2006). The business case for gender equality and diversity is linked to becoming an employer of choice, which is dependent on various criteria to attract and retain women. In Australia, organisations can achieve employer of choice status by demonstrating leadership committed to gender equality and embedding accountability for gender equality throughout the organisation (WGEA, 2017a).

Terms and conditions of employment which progress gender equality are also necessary for an organisation to become an employer of choice, and can include flexible working arrangements, paid parental leave, telecommuting, part-time work and job-sharing, gender pay equity, mentoring plans for women, women's networks, and other support for parents, such as breastfeeding facilities and employer subsidised childcare (WGEA, 2017a). Innovative workplace practices are also emerging from organisations which have been awarded an Employer of Choice for Women citation and include providing domestic violence leave, implementing "all roles flex" where roles are flexible by default and providing unconscious bias training to managers (WGEA, n.d.(a)).

6. The future of cyber security: Addressing the gender gap

Drawing on the barriers and enablers identified in the previous section, this section examines several steps that may improve the participation of women in the cyber security workforce, and the ICT sector more broadly. We begin with a discussion of the current definitions of cyber security, and developing frameworks for the professionalization of the cyber security workforce, which may have a limiting impact on women's participation in the sector. Next, we move to a discussion of measures to improve the transparency around pay levels and career progression in historically male-dominated areas, and how these initiatives may be harnessed to improve the representation of women in cyber security.

6.1 Redefining cyber security

Australia is increasingly focused on cyber security as an important national security and workforce issue. In 2016, the Government released *Australia's Cyber Security Strategy* (Department of the Prime Minister and Cabinet, 2016) which lays out a plan to build a national cyber partnership among governments, businesses, and the research community to develop and expand public and private sector capabilities around cyber security. As part of this initiative, the Government has committed to addressing the shortage of cyber security professionals by pairing with private sector firms and academic institutions to improve cyber security education "at all levels of the education system" (Department of the Prime Minister and Cabinet, 2016, p. 53). Improving the participation of women in the cyber security workforce is another of the government's stated aims.

Traditionally, the cyber security industry has drawn professionals from the STEM disciplines, including information technology and security. Other non-technical specifications crucial to building the cyber security workforce include: business management, risk assessment, business intelligence, consulting and process skills, operations management, and human resource management (Potter and Vickers, 2015). These important skills are frequently overlooked in strategic documents aimed at addressing the workforce gap in cyber security. For example, the Australian Government has begun to develop professional frameworks to define the qualifications required to become a cyber security professional. Based on initiatives developed in the United States and replicated in Singapore and the United

Kingdom, these frameworks are technical and STEM-based in nature, and classify cyber security staff according to technical knowledge, skills, and ability. They also require technical certification as an addition to academic qualifications in computer science, information technology, or engineering. These are all domains where women are chronically and historically underrepresented, a phenomenon that has proven highly complex and difficult to correct (Bell and Yates, 2015).

6.2 Retention of women in STEM and ICT

As shown in this literature review, the attrition of women from STEM and ICT is severe and shows little signs of slowing. Whilst rates of attrition for the cyber security industry are unknown, it is likely that more needs to be done to retain women. Women are concentrated in the lower levels of the ICT industry, therefore, retaining women and facilitating their career progress is necessary to ensure the continued viability and effectiveness of the industry (Reed et al., 2017, p. 9). Surveys of women in STEM suggest that many women want professional roles that enable them to work within a culture that provides flexibility and enables integration of work and caring responsibilities, and provides stimulating, interesting and challenging work (Hewlett et al., 2008; Hunt, 2010).

Increasing women's participation of women within STEM, ICT and the cyber security sector requires systemic and organisational change. Measures needed include eliminating and preventing discrimination, harassment and bias, establishing clear career paths and supporting mentoring and other development opportunities for women (Percival, 2016; Hewlett et al., 2008; Hill et al., 2010; Hunt, 2010; Loehr, 2015; Tan, 2013). Organisational culture change measures are also needed to counter the "chilly climate" for women (Wright, 1997). The following section details significant initiatives which have been undertaken to progress gender equity.

6.2.1 Increasing transparency and accountability

To redress gender gaps in both pay and seniority, many organisations are adopting more transparent and accountable reporting practices. Australia was one of the first OECD countries to institute a structured protocol for reporting on gender diversity (KPMG and ASX, 2011), and is now a world leader in gender data reporting. Gender diversity datasets operated by the WGEA and the Australian Bureau of Statistics (ABS) have created new levels of transparency around gender segregation and the gender pay gap across nearly all sectors (Senate Finance and Public Administration Committees, 2017). Furthermore, since 2011, the Australian Stock Exchange (ASX) has also begun to formally require listed entities to develop a diversity strategy, including measurable objectives, and either disclose those initiatives or provide a reason why no disclosure has been made.

Although aggregate data reporting allows for big-picture analysis of gender inequalities, many employers still do not conduct internal pay audits. A handful of Australian companies are not only conducting these audits, they are taking accountability a step further by publicising the results. In the financial services sector, which had Australia's largest gender

pay gap in 2015/16 at 25.9 per cent (BCEC and WGEA, 2017, p. 18), several firms have recently begun taking public steps to address the wage gap. The Big Four accounting firms, including Ernst & Young (EY), Deloitte, KPMG, and Pricewaterhouse Coopers (PwC) are among a handful of large Australian companies publishing the results of their gender pay audits publicly (see, for example, King, 2015).

Within the ICT sector, several major technology companies in the United States have also begun voluntarily disclosing their Equal Employment Opportunity disclosure forms in the interest of generating debate about the lack of diversity in the industry. Most notably, Google disclosed its internal diversity statistics (Google, 2014), revealing that men held 79 per cent of leadership positions within the company, while women made up only 30 per cent of its workforce and 17 per cent of technical workers. The company attributes the lack of diversity, in part, to the low representation of women among computer science and information technology graduates. Since 2014, other major technology companies, including Twitter, Intel, Facebook, eBay, LinkedIn, Microsoft, Amazon and Apple have followed suit (Molla and Lightner, 2016). Across these major technology companies, women's representation averages around 29 per cent (Ricker 2015). As these transparency initiatives are still relatively new, the extent to which will foster more diversity in the technology sector is as yet unknown.

6.2.2 Increasing flexibility

Employers are increasingly recognising the need to provide flexible working arrangements to attract and retain female employees. As discussed in 'The Business Case for Gender Equality in Cyber Security' section earlier, organisations, as well as employees benefit when able to work flexibly. Flexibility includes employees working changing their working patterns and working different days, reducing working hours to incorporate part-time work and job-sharing; changing work locations or working from home (WGEA, undated (b)). Flexible working arrangements complement employee entitlements such as paid parental leave and carer's leave. Flexibility can also be informal or formal, and as per the *Fair Work Act 2009*, Australian employees have a right to request flexible working arrangements (to change their hours of work, patterns of work or location of work (s. 65 Fair Work Act)).

6.2.3 Rethinking the culture

The existing literature on culture change is extensive, having developed into one field within human resource management and widely applied to organisational change efforts (for a standard example of culture change literature, see Kotter et al., 1996). Such research identifies the various steps needed to be implemented to change organisational culture, which include conducting a situational analysis, managing resistance, attaining some early wins, and involving all employees (Kotter and Schlesinger, 2008).

Other researchers focus on changing culture to reduce or eliminate the stereotypes and biases (see for example, Warren 2009). This approach involves engaging senior leaders in interactive dialogue to facilitate the establishment and development of diverse leadership

teams, and involving human resource professionals, line managers, and employees. Increasing the understanding of the “business case” for increased diversity can enable the development of strategies to increase the advancement of women and reduce the effects of gender. Finally, cascading goals and priorities facilitates the development of diverse teams which are then accompanied by other diversity management initiatives.

A newer body of research is emerging which adopts an interventionist approach to changing organisational cultures to become more inclusive. Researchers believe that “action learning” is transformative by not only precipitating culture change, but also by turning organisations into “learning” organisations. Action learning is defined as operating “through powerful feedback loops and constant inquiry into issues underlying developmental challenges, reinforced through the collaborative, reflective experience of participants” (Nelson et al., 2012, p. 294). Action learning relies on managers and employees being responsible for their learning, for designing and implementing their own change management activities, sharing these lessons with colleagues, then learning from their experiences as the cycle starts again.

Yet others have built on this model to enable culture change which specifically aims to redress gender inequity in organisations. Ely and Meyerson (2000) propose a framework that “disrupts” gender through systemic workplace interventions in which workplace participants critique gendered organisational practices, reflect, and experiment with new ways of working. Similar to action learning, this disruption of gendering in organisations needs to include long-term and short-term plans for change, with feedback loops, active involvement of all parties and experimentation (Benschop and Verloo, 2011; Eriksson-Zetterquist and Renemark, 2016). The difference with these models is that they are specifically focusing on analysing and identifying elements of organisations which reproduce gender biases and then engage participants to develop appropriate and interactive remedies.

6.2.4 Discrimination and harassment

Establishing a zero tolerance of discrimination, sexual harassment and bullying in the workplace, in line with legislated requirements, is the responsibility of senior leaders. This may include ongoing education about behavioural expectations and information about what behaviour is acceptable and not, and providing effective processes that enable the safe reporting of discrimination, sexual harassment and bullying in the workplace (Australian Human Rights Commission, 2013, p. 41), and senior leaders taking immediate action when reports are received.

6.2.5 Career progression and development

The lack of a clear and transparent career path is a significant issue for women in STEM and ICT. Masculinised cultures, which may include a “boy’s club” reproduce gender inequality. As detailed in this literature review, male employees in STEM are more likely to progress in their careers through informal networks and being “tapped on the shoulder” (Hewlett et al.,

2004; Hunt, 2010). A lack of networking opportunities for women in STEM and ICT can preclude women from such opportunities. Further, women are more likely to work part-time than are men, resulting in lower visibility than male employees and not being offered similar opportunities (Williamson and Colley, forthcoming). As women are often in subordinate roles and rewarded accordingly, the documentation of clear roles and reporting structures with equally clear capabilities and skills will provide all staff with a clear understanding of what is required at each level and what is needed at higher levels. Further, job analysis is required to identify any gendered elements of jobs and to ensure pay parity.

Women in STEM report a sense of isolation and a lack of role models (Reed et al., 2017; Hewlett et al., 2004; Hunt, 2010; Loehr, 2015; Tan, 2013; White and Massiha, 2016). They report a desire for mentors and sponsors and for established networks. However, these mentors and sponsors may need to be male, as women reported avoiding each other at work as they believe the power within the organisation lies with the men and being associated with a “women’s group” inhibits their success (Hewlett et al., 2008, p 11). These arrangements need to be formalised with the support of senior leadership (Hewlett et al., 2008). Further, expanding the recruitment challenge to recruit women into senior roles by focusing on their potential rather than their specific experience and work history with cyber security (Department of the Prime Minister and Cabinet, 2017; Hewlett et al., 2008; Hunt, 2010) will help establish female role models in the industry.

7. Conclusion

This literature review was conducted to test PM&C's initial findings examining the low participation of women in the cyber security industry. PM&C identified a number of barriers through exploratory research which may be contributing to women's low participation. This literature review commenced with an overview of women's participation in the global and Australian cyber security industries, provided a historical overview which showed that women have not always been under-represented in the industry, and then examined women's participation through education stages and the career life cycle.

The barriers and enablers to increase the numbers of women in STEM and the ICT professions have been clearly identified in research, and in this literature review. The barriers and enablers to women in cyber security, however, are less known. The main barriers to women in ICT include a lack of workplace support, isolation, lack of role models, a hostile work climate, discrimination and harassment and working conditions which are not compatible with working in an industry with long hours, particularly for parents and others with caring responsibilities.

This literature review has identified a number of research gaps. While there is an extensive, and continually growing, body of research into STEM and ICT on an international basis, less research has been conducted in Australia. There is no baseline data regarding the number of organisations participating in cyber security, their location, size, roles, employment models, recruitment, promotion, performance management processes or their employee demographic data. Similarly, while a small amount of research into women's low representation in cyber security has been conducted internationally, there is little comparative data available in Australia.

Additionally, while the research on STEM and ICT suggests that PM&C's findings may be correct, further research is required to explore the nuances in these high level findings. Existing STEM and ICT research has shown that barriers to girls and women commence early – from primary school – and continue throughout women's career to the executive levels. Barriers in ICT also exist at all stages of the employment life cycle, from recruitment to career development and performance management, culminating in women leaving the industry. Significantly, drawing on other STEM and ICT industries has enabled the authors to suggest ways to address the gender gap in the industry. Research is now needed to determine whether these strategies would be applicable to the cyber industry, within a framework of examining individual level barriers, as well as systemic barriers existing in the structure, processes, and cultures of organisations.

Appendix

Methodology

In compiling this literature review, we have examined both the academic and practitioner literature on cyber security. Dozens of journal articles, books, industry reports, government data sets, news and magazine articles on the subject of women in cyber security were reviewed for this literature review. Where gaps occur in that literature, we have examined trends and findings in related domains, such as STEM and ICT.

Theoretical Framework: Gendered organisations

This literature review has identified many of the barriers to women entering and remaining in ICT and cyber security, emanating from structural and systemic societal issues which impede the progression of gender equality, and the continual reinforcing of gendering processes at the organisational level. In conducting this review, we have used a theoretical framework examining how socio-cultural norms and processes within organisations reinforce gendered roles, and maintain and reinforce structural gender inequality (Acker, 1990). This approach holds that organisations are not gender neutral; rather, they inscribe gendered practices, social mores, and norms on individuals.

Mechanisms to “redo gender” in organisations include dismantling occupational segregation (which again, may include increasing the numbers of women working in ICT) and mainstreaming flexible working arrangements, for both men and women (Abrahamsson, 2014, p. 129; Charles, 2014, p. 378). Ely and Myerson (2000) recommend that to achieve a gender equitable organisation, an approach be adopted which centres on “disrupting” gender through systemic workplace interventions. This involves workplace participants critiquing gendered organisational practices, reflecting, and experiment with new ways of working and implementing human resource policies to address gender bias at every stage of the employment life-cycle and within organisational cultures.

Gender equality also needs to be mainstreamed throughout an organisation, commencing with an examination of human resource practices, formal and informal work practices and procedures, narratives and social interactions (Williamson and Colley, forthcoming). Progressing gender equality also requires recognition of the fluidity of gender and dismantling the gendered construction of jobs and organisations (Williamson and Colley, forthcoming). In conclusion, while specific practices can redo gender, an approach to address systemic and structural mechanisms which entrench gender inequality reside in more significant and large-scale workplace interventions.

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