5 Stem education and women entrepreneurs in technology enterprises: explorations from Australia

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<a> 1. Introduction

Even though the entrepreneurship literature is overloaded with studies emphasizing innovation-driven entrepreneurship, gender issues in these types of entrepreneurial ventures are essentially neglected (Brush et al., 2004; Ozkazanc-Pan and Muntean, 2018; Ranga and Etzkowitz, 2010). Considering technology entrepreneurship as gender neutral, the literature lacks observations of the relationship between gender and entrepreneurial activities in high-growth, high technology, and knowledge-intensive business sectors (Dy et al., 2018). A number of recent studies have started to examine the positive relationship between gender differences in science, technology, engineering, and mathematics (STEM) education and entrepreneurship (Blume-Kohout, 2014). In particular, the findings of a study (Dilli and Westerhuis, 2018) clearly shows that the high gender gap in science education enrolments reduces women's entrepreneurial activity in knowledge-intensive business sectors.

The study by Dilli and Westerhuis (2018) points out that, on average, the probability of finding female entrepreneurs in highly knowledge-intensive business sectors is 25 percent higher in countries that achieve gender equality in science education compared to countries that do not. However, this relationship is not automatic as the analysis of individual countries included in the study (i.e. 19 European Union (EU) countries and the United States of America (USA)) shows different trends (Dilli and Westerhuis, 2018).

Educational background generally reflects an aspect of the exploration of the individual characteristics of entrepreneurs (Cetindamar et al., 2012). However, educational organizations are embedded in institutions that collaboratively influence not only the educational access of individuals but also their occupational decisions after graduation (Bergman et al., 2018). That is why any study considering women as entrepreneurs in technology-based areas needs to also seek to understand institutional factors, such as being excluded from certain technological fields and positions (Cetindamar and Beyhan, 2018; Ding et al., 2007; Faltholm et al., 2010). In other words, empirical studies about women's entrepreneurship need to develop knowledge of different institutional environments. One such empirical study, the Global Entrepreneurship Monitor (GEM) (2012) report, shows that the ratio of companies owned by women to companies owned by men varies a great deal from country to country: the lowest being two percent, in Suriname and Japan, and the highest being 41 percent, in Nigeria and Zambia. Another study (Thebaud, 2015) confirms the differences across 24 industrialised countries, pointing out institutions in the form of work-family being the main reason for these differences.

That is why the purpose of this article is to draw attention to the relationship between STEM education and women's enterepreneurship in technology enterprises by using institutional perspective. To do so, we conduct a case study in Australia, as an example of a particular institutional environment. Even though our study is a preliminary research based on secondary resources, we still hope to explore some key factors that might explain why increasing the number of women entrepreneurs in high tech ventures is not an automatic outcome of higher involvement of women students in STEM fields.

The article has five sections. After this short introduction, in the second section we will demonstrate the strong link between STEM education and women's entrepreneurship in high technology sectors. The third section then explains the methodology used for this article, followed by the fourth section, presenting an Australian case study. In that section, we will explain developments in Australia as they relate to gender equality, STEM education and employment, as well as female entrepreneurship in high technology sectors. It will also introduce a recent program, called Science in Australia Gender Equity (SAGE), aimed at improving the gender gap in STEM education. In addition, we conduct an analysis of a specific educational institution that is a member of SAGE, namely the

University of Technology, Sydney (UTS). The goal is to illustrate a specific implementation of the SAGE program in a real-world context. The fifth and final section discusses the findings and insights gained from the analysis of the Australian example, and concludes with suggestions for further studies.

<a> **2. Unveiling the relationship between STEM education and women entrepreneurs in technology enterprises**

Female technology entrepreneurship remains outside the scope of entrepreneurship studies (Marlow and Dy, 2018), perhaps because women generally have proportionally less involvement (as a population) in science and technology-related education and, therefore, in STEM jobs (Orser et al., 2012). However, the scarcity of data concerning technology entrepreneurship by women makes it extremely challenging to pinpoint the problems that prevent women from participating in, or founding, science and technology-related businesses (Ozkazanc-Pan and Muntean, 2018). That's not to say that there are no STEM women entrepreneurs, simply that women in technology-based areas seem to struggle against institutional factors, such as being excluded from certain technological fields, particularly from positions associated with design and innovation, or access to social networks (Faltholm et al., 2010; Murray and Graham, 2007). This then affects the entrepreneurship pipeline.

This article focuses on female entrepreneurs in technology fields and attempts to tackle the limitations of the existing literature by focusing attention on the exploration of the relationship between STEM education and women entrepreneurship in technology sectors.

Although women's engagement with higher education is increasing, the gender gap across certain disciplines and seniority levels is still central to academia. For a long time, enrolment of female students in tertiary education was the problem. However, policies focusing on closing the gender gap in tertiary education and encouraging women to access higher education have yielded positive outcomes. An OECD (2012) report reveals that the number of female students in tertiary education exceeded that of male students in most of the countries except Germany, Korea, Japan and Turkey (Sugimoto et al., 2015). Eurostat statistics show that in 2015, the percentage of female and male population (aged between 30 and 34) who have successfully completed tertiary education was 43.4 % and 34 % respectively in the EU28 countries (Eurostat, 2016). Women are embracing higher education – but not necessarily in STEM.

Therefore, although women's access to tertiary education has been increasing, due to gender stereotypes, women prefer to be educated outside STEM fields (Dilli and Westerhuis, 2018). The causes for the under-representation of women in these fields can be multi-factorial: a desire for work-life balance, the self-efficacy and lower self-confidence of women in mathematical or scientific fields, and the lack of role models and parental encouragement (Cech et al., 2011; Sax and Bryant, 2006), plus a number of other reasons. EU statistics show that the number of higher educated female graduates in mathematics, science and technology fields per a thousand persons aged 20-29 in 28 EU countries is 11.2, while the same number is 22.9 for males (Eurostat, 2016). Compounding this situation, a recent investigation (Dilli and Westerhuis, 2018) shows how the enrolments of women into STEM have been unilaterally dropping across countries since 1970.

Gender inequality is not just rooted in women's limited access to – or uptake of – tertiary education in science and technology-related fields. Even after accessing tertiary education and pursuing an academic career or equivalent professional career for women, most women face formal and informal hurdles/barriers that restrict their achievements during their working lives. Studies reveal that female scientists produce fewer scholarly outputs, for example, which is problematic, as scholarly output is linked to academic advancement. Moreover, academic works with women as the first author receive fewer citations than those with male-first authors; and, unfortunately, this is valid across various disciplines and countries (Lariviere et al., 2013). Merit-based evaluation and promotion systems in academia, that rely on these markers as measures of competence, success or impact, therefore lead to fewer positions offered to female scientists and fewer opportunities for senior and executive positions. The antecedents of this productivity problem, however, are mostly ignored and male and female scientists are treated as having equal opportunities. Lariviere et al. (2013) point to women's networks as the cause of low productivity and low influence. While male scholars have better chances of accessing international networks, female scholars are mainly confined to national or local networks. Therefore, they suffer from a lack of adequate resources and cannot exploit the benefits of internationally collaborative networks to the same extent as their male counterparts do (Abreu and Grinevich, 2013; Ozkazanc-Pan and Muntean, 2018). West et al. (2013) argue that while the gender gap in the number of publications is closing, there is no significant change in how women are allocated more prestigious author positions in publications and in the number of solo-female-authored publications. Since hiring or promotions in academia are largely based on the number of publications by an individual, and their influence, women's careers and chances of rising to senior positions are directly influenced by these factors.

In fact, as studies indicate (Acker, 2006; Bird, 2011), gendered cultures within universities play a crucial role in shaping academic identities and careers. A general factor linked to this is the strong 'masculine' culture of traditional science workplaces. When the majority of the people working in science departments and laboratories are men, women can feel unwelcome, marginalised and intimidated by the atmosphere of such places. Women constitute only between five and 15 percent of technology entrepreneurs within Europe, and register a fraction of the patents for innovative products and processes (Wynarczyk and Marlow, 2010).

A leading question is, how are those types of hierarchical environments more masculine-supportive? Masculine culture materializes itself in power relations, the underlying structures and governance mechanisms (Karatas-Ozkan et al., 2015). A study (Rosa and Dawson, 2007) about female founders of United Kingdom (UK) university spinout companies in 20 leading universities shows that the proportion of female founders is 12 percent. This is not surprising since, according to the 1999 data, 11.6 percent of professors in UK higher education were female, and women represented only 3.1 percent in engineering and technology faculties. When a woman is much less likely to become a scientist, she is, therefore, also less likely to become a science entrepreneur. That is why women are especially under-represented in the categories of science, innovation and entrepreneurship (Kyrö and Hyrsky, 2008).

There is a need for new mechanisms to change attitudes towards, and perceptions of, women, and positively shift environmental and institutional factors. Ding et al. (2007) and Murray and Graham (2007) suggest that the gender gap among younger generations is closing. One reason is the equal mentoring by commercially active and, most probably, male advisors. One hypothesis is that female scientists who get mentoring about technology commercialization in the early stages of their career would probably attempt to access and build larger industry networks. Not having larger industry networks is a significant factor that prevents women from participating in entrepreneurial activities (Murray and Graham, 2007; Ding and Choi, 2011; Abreu and Grinevich, 2013; Faltholm et al., 2010). In order to mitigate this problem, women scientists use technology transfer offices (TTOs) as a mechanism that enables them to access industry (Colyvas et al., 2012; Goel et al., 2015). Apparently, development and improvement of such intermediary mechanisms can play an important role in female technology entrepreneurship (Oster et al., 2012). We expect that improved representation at senior levels will challenge the dominant masculine culture and both directly and indirectly increase women's representation in organizations.

<a> **3. Methodology**

Due to the nature of the research goals and the lack of empirical studies in this field, we are using a single case study method (Yin, 2009) for this paper. By using the Australian case study, we aim to present information about STEM education and women entrepreneurs in high tech for a certain type of country. We focus on the secondary data provided by public and private organizations. Polkowska (2013) uses statistical information provided by Eurostat to explain the barriers that women face in commercialization in science. Koster (2008) uses secondary data from various resources to investigate the linkages between economic development and entrepreneurship in India. In case study analysis, using multiple resources is important (Yin, 2009).

In order to seek out existing academic studies about Australia, we conducted a systematic literature review by using the ISI Web of Science (WoS) Core Collection database to find all the literature on the topic that could be of interest. When using the 'topic' field to search the database, ISI-WoS returns all articles with the search terms in their title, keywords, or abstracts. Scholars in management science consider this database to be the most comprehensive and use it frequently in systematic reviews, as discussed indetail by the study of Hausberg and Korreck (2018). We made a search by using the search terms 'women entrepreneur*' and 'Australia' for the period of 2000-18 in November 2018. We combined the search terms with the constraint that it has to appear in one of the following WoS-categories: management, business, economics, and women studies. By this restriction, we ended up with a result of 16 articles. The topics of these papers range from franchise issues to immigrant women entrepreneurs. None of them analyse the topic of women entrepreneurs in Australian technology ventures and we did not come across any coherent and comprehensive view of women's entrepreneurship in the Australian high technology industry except the Dell (2017) study that is limited to the analysis of the Sydney entrepreneurial ecosystem.

We tried to utilize all relevant data available from secondary sources regarding STEM education and women technology entrepreneurs in Australia. Data came from a wide variety of national and international sources such as the Workplace Gender Equity Agency (2018) or Global Entrepreneurship Monitor (2017). We present macro data on Australian women's labour participation, gap pay, female and male industries, STEM education and technology entrepreneurship, in order to provide the country's context. Then, the study presents the SAGE program and its pilot application at UTS to give an idea of a specific institutional intervention in Australia that could help to create a bridge between STEM education and female entrepreneurship in STEM fields.

<a> **4. Investigating Australian Practices and Institutional Factors**

<b> 4.1 General Gender Issues

Australia is one of the world's advanced economies. However, it has low performance in gender equity comparative to its economic performance, both measured by World Economic Forum (WEF) indices. According to the Global Gender Gap Index reported at WEF 2017, Australia ranked 35th out of 144 countries (WEF, 2017). The Global Gender Gap Index examines the gap between men and women in four fundamental categories (sub-indexes): Economic Participation and Opportunity, Educational Attainment, Health and Survival, and Political Empowerment. Among these sub-categories, Australia ranked one in educational attainment, 42nd in economic participation and opportunity, 48th in political empowerment and 104th in the health and survival category. There are two concerns related to gender performance of Australia: 1) compared to its rank of 12th place in 2006 out of 115 countries, it seems the Australian position on gender equity has significantly declined, and 2) its gender equity is disproportionately below its economic success, considering that the Australian economy is 21st out of 144 countries in 2017.

<c> ***4.1.1 Participation***

Most Australian women are in paid employment, but their participation still lags behind that of men, with approximately 60 percent participation compared with 71 percent by men. In fact, Figure 5.1 shows that only about 35 percent of women are in full-time paid employment, and, of employed women, part-time positions make up the largest proportion. What this means is that women continue to have reduced access to the leadership pipeline and higher paying roles, as only an estimated 6.3 percent of management roles are part-time. There are also multiple repercussions for equity and prosperity over a lifetime. Average full-time weekly earnings for women are $1409, compared with men at $1662.70 (Workplace Gender Equity Agency (WGEA), 2018; Australian Human Rights Commissions (AHRC), 2018), though in some industries the wage gap is significantly higher. In financial services, for example, the disparity is approximately 34 percent (WGEA, 2018). The cumulative effect of these experiences is that Australian women retire on just more than half of the superannuation savings (58percent) of men (CEW, 2017). A compounding factor is that women are the society's primary care-givers: 70 percent of unpaid primary carers for children are women and 58 percent of the primary carers for the elderly, and people with a disability or long-term health condition, are women (AHRC, 2018). They also live longer than men do.

*** Insert Figure 5.1 ***

Discrimination against Australian working mothers is also prevalent, with 50 percent of women reporting workplace discrimination because of their pregnancy, parental leave or return to work after the birth of a child (AHRC, 2018). Sexual harassment, physical or sexual violence and violence from a partner are also part of the personal landscape of Australian women, with half experiencing sexual harassment and one in three women over the age of 15 experiencing physical or sexual violence (AHRC, 2018).

However, this current landscape of discrimination is at odds with Australia being acknowledged as one of the world leaders in the 2006 Gender Gap Report at the WEF (Barns and Preston, 2010). A closer look at the analysis of that time seems to reveal it as being due to the increased participation rates reported in the area of part-time employment, low paid or precarious work (Barnes and Preston, 2010), a questionable consideration. In short, although arguably ahead of many countries at that time, having now slipped to a rank of 35 (AHRC, 2018), progress for women and girls is challenged as a practical reality in recent history in Australia and is, in fact, going backwards.

There is also a query about the way participation rates, and other WEF Gender Gap Index categories are measured, may not be appropriately applied and 'fail to capture the nuances and complexities of women's everyday lives' (Barnes and Preston, 2010). This implies that improved parity from social mobility, advancement and economic perspectives remain aspirational, and women continue to be locked out of more senior, potentially better paying, roles, and access to economic and financial security. In addition, the role of measurement comes into the spotlight, to help more usefully track progress and disadvantage. Encouragingly, in 2013 the Australian Council of Governments (COAG) launched its first national report on gender.

Some things, though, are changing. More women are now graduating from Australian universities than men (100 women for 80 men) (CEW, 2017), so there is an opportunity for improved employment access and participation in the future, especially if other barriers can be addressed.

<c> ***4.1.2 The gender pay gap***

Though women now outnumber male university graduates, female graduate salaries are 3.6 percent lower than males (CEW, 2017), which is an improvement on recent years, where male starting salaries were about 9.6 percent higher (CEW, 2016). This earning disparity then increases over time, reaching a peak disparity between the ages of 45 and 54 (WGEA, 2018), at which time men earn an average of 20 percent more than women do. Referred to colloquially as the peak earnings period, the implications for the future economic security of women, is, by then significantly compromised.

According to the Workplace Gender Equity Agency (WGEA) report of February 2018, there remains a pay gap of approximately 22.4 percent for non-public sector organizations with 100 or more employees, so men working full-time earn nearly $26,527 a year more than women working full-time do. On average, though, it sits at about 15 percent, across public and private sectors. In some industries, however, the disparity is much greater. The pay gap is widest in the financial services and insurance sector (34.7percent), followed by the real estate (30percent) and construction (29percent) sectors, and lowest in the public sector. The fairest industries for male/female pay are public administration and safety (8.2percent gap), and accommodation and food services (6.3percent); followed by education and training (12.3percent), then healthcare and social assistance (13.3percent). The financial services and insurance sectors are also one of the bigger employment sectors for women who make up approximately 55 percent of the workforce, and yet, has the largest overall pay disparity.

When analysed for STEM-based employers, in the top six industries to employ STEM graduates, as seen in Figure 5.2, there is a spread of disparity, from high wage gap to lower-end gap. Professional, scientific and technical services, for example, have a gap of 26 percent compared with 15 percent in manufacturing. This means that women entering STEM workplaces are likely to continue to have differing work experiences than their male counterparts.

*** Insert Figure 5.2 ***

<c> ***4.1.3 Female and male industries & STEM***

Figure 5.2 shows the biggest employers of women in Australia are: healthcare and social assistance (80 percent female workforce), education and training (63 percent), retail (58 percent), financial and insurance (55 percent), accommodation and food services (hospitality) (52 percent), and arts and recreation (50 percent). However, these industries do not offer the highest paying jobs at executive levels with the exception of finance and retail. Although the public administration sector has one of the lowest wage gaps, it is also one of the lowest employers of women, with a 79 percent male workforce. Other industry sectors that have predominantly male workforces are mining (84 percent), construction (83 percent), utilities (76 percent), transport (74 percent), and manufacturing (74 percent). In the top six industries that are significant employers of STEM graduates, women can expect an average pay disparity of about 18 percent, with a range from eight to 34 percent.

Another area where industries vary widely is in relation to leadership attainment. Seemingly, in the STEM sectors that employ a proportionally higher number of women, there is a higher level of female seniority attainment as shown in Figure 5.3. In the healthcare and education sectors, for example, the head of the business or CEO is female 37.5 percent and 35 percent of the time, respectively. That said, given that the workforce is 80 percent and 63 percent female this is still a significant decline in representation (a disparity of 44 percent for healthcare), although 'as good as it gets', in terms of female executive leadership in the Australian context (37.5 percent). The highest disparate representation between workforce gender and CEO is the financial services sector, with a 50 percent gap.

*** Insert Figure 5.3 ***

<a> **4.2 STEM education**

Australia is a relatively ‘late adopter’ (Blackley and Howell, 2015) to the emphasis on STEM education. However, the movement has been rapidly gaining pace since 2013 following the publication of a number of influential papers arguing that STEM education will be vital to the future environmental, health, food, water, energy and economic needs of the country. The Australian state and territory governments signed the National STEM School Education Strategy 2016-2026 in December 2015, marking a significant step forward for the national STEM agenda.

That said, the number of women doing undergraduate studies in STEM fields in Australia has declined slightly over the past ten years, from approximately 38 percent to 35 percent of total student intake (see Figure 5.4). However, of those women that do study STEM, a slightly higher number are now pursuing post-graduate qualifications, up from 27 percent in 2006 to 33 percent in 2016.

*** Insert Figure 5.4 ***

There is also the question of whether the students are local or international, as a major and growing industry for Australia is that of tertiary education. It is unknown what proportion of the female STEM students are international, so the actual picture of the state of STEM education for residents of Australia and Australia’s future STEM capabilities may not be represented by these statistics: further investigation of this possibility is warranted. Although a number of international students will seek to remain in Australia after graduation, potentially for the medium to longer term, most return to their countries of origin, taking with them their STEM qualifications and future potential. In health studies, women continue to be the dominant population, making up approximately 74 percent of the undergraduate students and 72 percent of the post-graduate students (see Figure 5.4).

Consideration of the pathway beyond post-graduate study includes the possibility of the pursuit of an academic career. Though most post-graduates go on to private sector or public service careers, some will consider their involvement in academia. Of those that do, there is a distinct dropoff in academic seniority between Level A/B (Assistant Lecturer in the Australian higher education system) and Level E (corresponding to Professor) ranks for women. The question arises as to why women's academic careers falter beyond Level A/B. Men's careers, in contrast to most women, accelerate beyond A/B, with disproportionately fewer women attaining senior academic roles. Factors affecting women's academic career trajectories include among others: equity in gaining ongoing secure employment; the availability of supportive, flexible workplaces during family formation (that also encourage men to have a role in family life); and the availability of re-entry programs to support workforce re-engagement for primary caregivers. Social factors, such as networks and isolation, may also play a part. Again, this aspect of the topic warrants further investigation.

<b> **4.3 Technology entrepreneurship and entrepreneurship**

Given that technology access and literacy impacts a person's ability to generate income, economic stability, or even wealth, it bodes well that a relatively high percentage of women in Sydney, the business and, arguably, technology capital of Australia, have access to the internet and own a smartphone, both respectively 89 percent (Dell, 2017). Australia remains behind many comparable countries with regard to access to high speed, fibre-based internet, though the rollout of the National Broadband Network, a Government program, is helping to improve this situation.

However, despite high access to technology, women are under-represented in Australian start-ups. In recent years, the start-up scene in Australia has gained significant momentum, particularly in Sydney, an emerging entrepreneurship centre, ranked 23rd in the Technology pillar of the Dell WE Cities 2017 report. Yet women (Dell, 2017) lead only one in four start-ups. Further, only 10-18 percent of venture-backed companies have a female founder (Dell, 2017). Access to capital is seen as a limiting factor in the success of most new businesses, especially those involving patents or spin-outs from a university context (Allen et al., 2007; Rasmussen and Wright, 2015) and it appears to be a limiting factor for female entrepreneurs also (StartupMuster, 2018).

In a review of female participation in total early-stage entrepreneurial activity across G20 countries (see Figure 5.5), where data was available, Australia ranks in the bottom 50 percent for female participation (the percentage of females who are in the process of starting a business), at 39 percent, with a rank of 11 out of 17. The top five countries with the highest female participation rates are Indonesia (55 percent), Brazil (51 percent), Russia (45 percent), Argentina (45 percent) and Saudi Arabia (42 percent). The United States just makes it into the top ten countries with the highest female participation rates, with a rank of 10 (41.5 percent), but is the only country in the top ten with an innovation-driven categorisation. In Australia, many commentators would be surprised, even shocked, to discover that Australia ranks behind Saudi Arabia, and China, in terms of female participation in entrepreneurship, though obviously country-based distinctions do play a role, and it is important to understand the contextual and cultural nuances. France and Germany, for example, have very low general participation in entrepreneurship, male or female, possibly due to the high level of social stability. In Australia, and other countries, participation in entrepreneurship can be a sign of potential disadvantage – necessity-based entrepreneurialism – rather than a progressive agenda.

*** Insert Figure 5.5 ***

For female participation in opportunity-driven entrepreneurial activity (the percentage of females as opposed to men who are in the process of starting a business out of opportunity, as opposed to out of necessity), Australia ranks third-last of all countries (behind Brazil and Argentina). It seems, as the study of Thebaud (2015) finds out in the study of 24 countries, women in Australia may tend to become business owners as Plan B, due to the prioritisation given to family over work and that is why their start-ups might be less growth-oriented ventures. However, this topic requires further research.

The majority of women do not benefit from progressive corporate policies on gender equity, where they exist. This is because just 36 percent of women are in fulltime employment (as shown above at Figure 5.1) and small businesses are the largest employer of Australians. Rather, women are falling through the cracks, and struggling to create a life for themselves that delivers the financial security they, and their dependents – their children, elderly relatives, disabled family members – need. Given that 81 percent (ABS, 2012) of single-parent families are female, and only 34 percent of single parent families with a child under five have an employed adult, the social impact of this is enormous. This may explain why the necessity-driven participation of women in entrepreneurial activities in Australia is surprisingly high.

Other factors may relate to the entrepreneurial environment (Brush et al., 2017). The mainstream start-up movement, for example, is not gender neutral (Marlow and McAdam, 2015): there is an inherent masculine bias. The dominant narrative of entrepreneurship is male, and reflective of the embedded societal bias (Marlow and Dy, 2018). 'Entrepreneur' is not a gender-neutral term, nor is 'the internet' or 'digital technologies' (Dy et al., 2017), though they are falsely perceived as levellers or equal playing fields. Ideally, the world of entrepreneurs is meritocratic – and yet, the gendered nature of that environment has implications for access to the resources required for entrepreneurial success, such as engagement with third parties, mentoring, access to role models and support networks (Clarysse et al., 2011; Karatas-Ozkan and Chell, 2015; Orser et al., 2012). These types of barriers inhibit the realisation of potential for female founders, and discourage entrepreneurialism in the first instance. In addition, personal factors, such as confidence and self-belief, without a supportive peer network, as well as exposure to entrepreneurism in their early career, play an influential role in women's entrepreneurial activity (Brush et al., 2017).

Given that nearly 42 percent of Level A academics (corresponding to research assistantship positions in Australia) are female (see Figure 5.6), a statistic many businesses would envy in terms of gender balance, the possibility of boosting female entrepreneurship from inside universities, before they depart or become discouraged, is one route to consider. However, despite efforts by the Australian Technology Network of universities to boost the number of businesses they give birth to, academic entrepreneurship remains low. Even members of the SAGE program have not been able to shift the dial yet.

*** Insert Figure 5.6 ***

The universities that do seem to be relatively successful in creating start-up companies as extensions of student work are the Australian Group of Eight (G8) universities: the older, most prestigious universities with the highest general and research reputations. The reasons why are not clear, but could be hypothesised as relating to access to capital and networks, typically required by any start-up, inside or outside academia, to get off the ground. Culture or environment may also be a factor. As shown in Figure 5.7, although UTS is slightly above average compared with all universities, and average compared with other technology universities, the G8 universities have consistently beaten all other categorisations in the number of start-ups created over the last few years.

*** Insert Figure 5.7 ***

<b> **4.4. SAGE Program**

A recent sector-wide approach in Australia, the SAGE Athena SWAN pilot, acknowledges that outdated workplace conditions and culture may be affecting the participation of women in STEM and medicine (M) research careers. The pilot is based upon the Athena SWAN accreditation framework from the United Kingdom that has been in place since 2005. While this pilot is in its infancy, with the first of three cohorts lodging applications for initial accreditation in early 2018 and the others in 2019, developments at one participant, the University of Technology Sydney (UTS), show that the pilot is already affecting university and faculty approaches to managing diversity.

SAGE is a joint forum of the Australian Academy of Science and the Australian Academy of Technology and Engineering, developed specifically in response to issues of gender imbalance in representation within the Academy, and in STEM and medicine more generally. SAGE states that one of the drivers of this change was an event in 2013 where the year's cohort of fellows elected to the Academy of Science was one hundred percent male (SAGE 2014).

In 2014, a forum and workshop was convened to consider measures to address unequal outcomes for women in the academy election process and STEM more generally. Discussion at the forum focussed on higher education participation and workforce presence, and noted that less than one in five professorial positions were then held by women in science, even though there is gender parity at the postdoctoral level. Figure 5.4 melds two data sets – student completion figures and cross-sector university workforce figures provided to the Commonwealth Department of Education, to attempt a representation of gender presence at each level of academic attainment. It shows that while women make up 40 percent of doctoral completions and 42 percent of entry-level academic workers, attrition of women occurs throughout this pipeline to create a highly significant under-representation of women at senior positions, dropping to around 10 percent at Level E positions as given in Figure 5.6.

While the impact on entrepreneurship was not specifically considered, one of the key workshop discussions related to ways that rigid academic structures impacted mobility across sectors, particularly where stints in industry affected publication rates and, therefore, the potential for academic career progression. Figure 5.7 bears this analysis out, showing that the number of start-up companies created from universities had decreased sector-wide over the years 2000-2015, despite consistently higher rates of conversion from the G8 universities. Workshop participants felt that disciplinary silos and silos between industry and higher education reduce the opportunity for collaboration and career pathways that mix industry and academic research expertise, to the detriment of all sectors. The workshop concluded that women disproportionately felt the impact of this lack of mobility, since their opportunities were more likely to be greater if there was greater mobility after career interruptions.

Reviewing the data, workshop participants concluded that gender equity in the sciences was a long-term project in Australia. To achieve a long-term elimination of gender imbalance in the sciences, a short-term indicator of success would be achieving widespread support in the sector for action to combat gender inequity. The outcome of this forum was to license to Australia the Athena SWAN pilot from the ECU with this aim.

Athena SWAN can be characterised as a continuous improvement program for gender good practice. A staged program, conducted in the medium and long term, requires the organisation, and its constituent faculties, schools or departments, to attain accreditation under the Athena SWAN Bronze, Silver and Gold Award scheme. Qualification for progression requires incrementally more leadership internally and in the sector, investment and evidence of progress in redressing gender inequality, with the organisation as a whole unable to progress past the bronze level award without individual accreditation of the majority of its constituent areas. In the United Kingdom, participation in the program was linked to eligibility to apply for some of the National Institute for Health Research funding, with a silver award required for shortlisting for Biomedical Research Centre funding.

In the first instance, 32 Australian national research and higher education bodies signed up to the ten principles of the Athena SWAN Charter and contributed subscription fees to participate in a sector-wide pilot in two cohorts. Later, this was expanded to a third cohort of eight additional institutions.

<b> **4.5. UTS**

UTS, a sector leader in equity and diversity already, had a strong reputation for innovative and progressive approaches to gender equity, holding the Workplace Gender Equality Agency's Employer of Choice award since its inception; and through the Research Equity Initiative that was implemented from the Office of the Deputy Vice Chancellor Research in 2012. This suite of programs provided targetted research support that women and primary carers could access to maintain research activity, outputs, and conference attendance during times of intensive carer responsibilities and on returning from parental and carers leave. The Athena SWAN program was arguably an extension of this sector-leader approach. As such, UTS applied to participate in the SAGE pilot in 2015, nominating successfully for the first cohort and commencing the pilot in late 2015, and was awarded an Athena SWAN Bronze Award with the first cohort of applicants in December 2018.

There was widespread executive support and championing of the pilot from the Vice Chancellor and senior university and faculty leadership. UTS adopted the ten charter principles and activly engaged in the process from the outset, with proactive engagement from STEM faculties. UTS included three faculties and two schools in STEM, the faculties of Science, Engineering and Information Technology, and Health, and the Graduate School of Health and the School of Architecture. UTS does not have a medical school but included the health faculty (comprising nursing, midwifery, sports and exercise science and public health) and graduate school of health (comprising psychology, pharmacy, orthoptics and physiotherapy) under the 'M' in STEM(M). UTS, as a member of the first cohort, followed a highly proscriptive pilot program with sequential training, working towards submission of the first bronze award applications in March 2018. This included appointing a senior Academic Lead of the pilot (Assistant Deputy Vice Chancellor Research), who chaired and established the UTS Self-Assessment Team (SAT) to oversee the award application and development of a four-year action plan to address gender inequity. The SAT was a university-wide committee with a gendered and diverse membership of academic levels. At a faculty or school level, equity and diversity committees were established to engage staff in the workplace around the investigation of gender equity in STEM(M). The SAT drove a program of collation and gendered analysis of disparate and varying fit-for-purpose electronic and paper-based human resources, recruitment, training, promotion, equity and diversity; and research metrics data to develop a snapshot of the current state of gender equity in its STEM(M) disciplines. Any gaps in the data were augmented by qualitative interviews and focus groups of academics and professional staff in STEM(M) to contextualise gender experiences in research in STEM(M). A gendered lens was taken to existing policies and practices with the qualitative research identifying barriers to effective policy implementation at an operational level in the faculties. Other data were sourced from routine sector surveys the university participated in, and combined with the quantitative and qualitative data aforementioned, to provide a comprehensive picture of the institutional structures, systems, and culture which contribute to gender inequity at UTS. In response to this, a four-year action plan was developed and signed off by the university executive to address gender inequity in its STEM(M) disciplines and more widely across the university from 2018-2022.

A major outcome to date of UTS's participation on the Athena SWAN pilot has been the compiling of evidence, by organisational level, showing differing pictures of gender inequity, and these have been successfully disseminated at all levels of the university. This had led to executive action and faculty and school ownership and engagement; a systematic reframing of gender equity to business-as-usual; and commitment to policy review and resourcing of the four-year action plan to progress gender equity at UTS.

Table 5.1 presents faculty profiles and areas identified for inclusive improvement, including UTS staff concerns such as the recruitment of women, particularly in areas where there are few women; promotion of women; increased conversion of post-doctoral fellowships to continuing roles; more effective staff induction programs; and workforce and organisational culture.

Table 5.1. Faculty profiles and areas identified for inclusive improvement as at 31 March 2017

Faculty	Number of schools	Overall gender balance	Gender distribution	Areas identified by staff and committees for focus
Engineering and Information Technology	5 Increased to 6 over life of pilot	Majority male	Women more concentrated at junior levels Segmented by discipline, related to gender profile of candidate pool Increase in proportion of women at senior levels over life of the pilot.	Recruitment of women, particularly in areas where there are few women Promotion of women Increased conversion of post-doctoral fellowships to continuing roles More effective staff induction programs
Science	2	Majority male	Women more concentrated at junior levels Segmented by discipline, with life sciences more balanced than mathematical and physical sciences	Recruitment Workforce development Workforce and organisational culture
Health	1 (5 internal disciplines)	Majority female	Men more concentrated at more senior levels Segmented by discipline	Recruitment and appointment of women Retention and professional support Workplace culture
Graduate School of Health	1 (6 internal disciplines)	Majority female	Men more concentrated at senior levels	Recruitment Development and promotion Workplace culture
Architecture	1	Gender balanced*	Women more concentrated at junior levels	Workplace culture

*within 45-55% range
Source: Town meeting held at 12 December 2017

Similarly, the initiatives taken by each faculty at UTS show a wide variety, as given in Table 5.2. The major initiative seems to be giving intentional focus on the recruitment of women to senior leadership positions, including direct appointments.

Table 2. Specific equity measures by faculty

Faculty and Focus	Initiatives
Engineering and Information Technology	Unconscious bias training for executive and unit heads
	Intentional focus on recruitment of women to senior leadership positions, including direct appointments
	Staff mentoring program established
	Formalised induction program
	Core meeting hours guideline
	Parental leave support – engagement of a post-doctoral fellow to continue research and engagement activities while an academic is on parental leave
Science	Recommendations to use direct appointments to amend gender balance
	Focussing recruitment language to attract and support female candidates
	Pilot evaluation of specific recruitment rounds to identify potential bias or process changes
	Review of discipline profiles to include equity concerns
	Access to specific professional development opportunities for identified female staff
	Letters of commendation from the Dean recommending particular community-building activities
	Dean's awards for community contributions – positive recognition of community-building activities undertaken by women in disproportionate measure
	Core meeting hours guidelines
	Events showcasing and celebrating women in STEMM
Graduate School of Health	Ensure gender balance on recruitment panels
	Develop a framework of cultural sensitivity across platforms to aid retention and recruitment
	Core meeting hours guidelines
	Gender-balanced representation on all committees
	Establishment of a mechanism to review workload guidelines
	Workshops and events focussing on discipline based cultural inclusion
Faculty of Health	Review recruitment processes for unconscious bias
	Review workload protocol with an "equity and diversity lens"
	Create standing item for equity and diversity at discipline and centre team meetings
	Review other faculty initiatives with a view to adaptation and adoption

Source: Town meeting held at 12 December 2017, Sydney Australia.

UTS engaged with the SAGE program to start to better understand how structural bias was affecting women and what was influencing access to opportunities. With a clearer view of how it functions as an institution a number of interventions, evolutions and processes can be put in place. Of the 40 higher education organizations within Australia who have now engaged with the SAGE program, UTS is one of the major supporters of women in STEM and entrepreneurship generally. Top management at UTS has rolled out a program of interventions to enhance the opportunities for women at UTS. The experience of UTS clearly shows the importance of institutions in shaping organisational interventions through the generation of a gender-inclusive environment for both STEM education and the workplace.

<b> **4.6. The Women in STEM Decadal Plan**

Addressing workforce and pipeline issues affecting women's participation in STEM research and business activity is an area of emerging national policy development in Australia, with possible positive impacts for STEM entrepreneurship activity. The Women in STEM Decadal Plan, launched in April 2019, has been developed by the Australian Academy of Science and the Australian Academy of Technology and Engineering at the request of the Australian Government (Decadal Plan, 2019). These bodies are also the sponsor bodies of the Athena SWAN pilot.

The purpose of the Decadal Plan is to provide a ten year roadmap to build sustained higher levels of engagement with STEM education and careers among women and girls, focussing on participation and retention from school through to the workforce, including outcomes related to:

- long-term improvements in gender equity
- improved quality in STEM skills and expertise in Australia
- increased access for women and girls to participate in STEM
- expanded career and study opportunities for women
- benefits to business from increased access to STEM skills.

In 2018, the Decadal Plan office released a discussion paper and conducted extensive industry and sector consultations around these matters. The discussion paper raised issues around STEM career paths, workforce culture and pipelines, and the value of diversity to business outcomes, and recognised the difficulty faced by many women in setting up small businesses both within and outside STEM streams. Questions for consultation focussed on addressing barriers to STEM careers and educational engagement, and asked stakeholders to outline areas where effort would be best placed in a strategic approach to improving life cycle participation. Submissions to the process were not made public. The launch of the Plan signals the conclusion of a significant program of work to map stakeholder and community responses to the challenge of addressing these issues.

<a> **5. Concluding remarks**

After highlighting the deficiency in the literature of studies on women's technology entrepreneurship, this paper argues that the entrepreneurship theory should take into account the role of organizational/institutional factors in order to overcome existing gender-blind frameworks available in the extant literature. To illustrate how institutional lens could improve our understanding of gender issues in entrepreneurship, this paper examines the link between STEM education and female technology entrepreneurship. In line with the findings of a few recent works (Dilli and Westerhuis, 2018), our study shows that even though STEM education could possibly lead into careers in entrepreneurship in tech ventures, this progression is not an automatic link. Many institutional factors are in play determining the outcome. For example, the Australian example shows that having successful programs in STEM education has to be complemented with clear programs related to entrepreneurship initiatives.

In addition, this paper contributes to empirical works of the entrepreneurship literature. It presents macro-level analysis of Australia as a case study, to understand how institutional factors in education, such as programs targeting the education of women in STEM fields, could increase the likelihood of women becoming entrepreneurs in technology ventures. The paper highlight few key lessons from the analysis of Australia case and proposes a number of policy suggestions that can be relevant to many countries searching ways of improving their female technology entrepreneurs.

<b> **5.1 Lessons from Australia**

Australia is not as progressive as may be assumed internationally when it comes to gender equality, and, in fact, has slipped backwards in recent years. Upon closer analysis, a perception of success closing the gender gap may be unpicked – participation rates include part-time work, low income and precarious work. Equal pay remains elusive, with pay gaps widening over lifetimes, and despite more women graduating from universities than men, the pipeline into management, senior manager, executive and board level roles drops away by mid-career. Pay peaks around age 45 and then slides, while men's continue to grow until their mid-50s. Infamously, women ultimately retire on about half of that of men, but live an additional five or six years. Only about 25 percent of Australian Stock Exchange-listed Top 300 companies board members are women (Australian Institute of Company Directors, July 2018), and women remain under-represented in political office, with one of the leading parties, in particular, currently in the midst of a gender crisis, following a leadership coup in August 2018.

Viewed as a vital capability for the workforce of the future, careers in STEM could offer women an opportunity for closing the economic gap and improving social mobility. The STEM education agenda has gained significant momentum in the last couple of years in Australia with significant results to reduce the gender gap. Both boys and girls are now more exposed to STEM throughout their education – from early childhood, through to primary and high school. Educational institutions have a key role to play, since their interventions can help to preserve the female STEM pipeline not just through the educational process, but also beyond, once these women are in the workforce. The Australian exercise of the SAGE program has such an intervention logic and it has been in practice since 2015. Since this program is a new one, its full impact will be realised in coming years. However, as a whole, SAGE is a well-regarded initiative that offers a constructive insight for an international audience to understand how organizations in Australia are attempting to address gender inequality starting with STEM education. In line with recent studies (Bergman et al., 2017), we believe that supportive organizational environments will, in turn, improve gendered cultures within universities thereby improving opportunities for women, and play a crucial role in shaping academic identities and careers for women in STEM fields, including entrepreneurial careers.

As Dilli and Westerhuis (2018) have pointed out, STEM education is the first step in the right direction for establishing careers in technology entrepreneurships for women. Australia seems to have a good starting point through programs such as SAGE in supporting STEM education and opportunities, but it seems to fail in taking the next step for women's entrepreneurship in technology fields. Given that nearly 42 percent of Level A academics in Australia are women, the possibility of boosting female entrepreneurship from inside universities, before they depart or become discouraged, is one route to consider for a positive long-term impact on a pipeline of female technology entrepreneurs. Thus, Australia should start considering complementary programs that could strengthen the link between education and entrepreneurship in STEM fields. It might be through either SAGE initiatives or new independent programs.

Australia laid a great example by producing organizational policies such as SAGE and the Decadal Plan that shows the commitment and stakeholder involvement in producing long-term policy agenda for STEM education and careers among Australian women and girls. Based on our observations from these policies that are strong institutional interventions, we would like to offer a few policy suggestions that might improve the relationship between STEM education and women entrepreneurship in high technology fields:

- A clear focus on technology entrepreneurship is absent from the national policy discussion on STEM education and careers. This is a fertile field for research calling for a focussed partnership approach between the Australian Government and the entrepreneurship sector, building on the Women in STEM Decadal plan.
- It would be beneficial to take a life cycle approach in the education system to build positive cultural attitudes encouraging women and girls to enter STEM fields. Such integrated education initiatives contribute to awareness of STEM careers too and exposure to female role models in STEM play a major part in developing girls' positive self-identity in STEM that can further help women to see STEM as an inclusive and viable career pathway.
- It is necessary to give access to scholarships and fellowships for women in STEM as a targeted policy measure to promote gender equality and achieve quotas to encourage more women participation in STEM education and careers.
- Organizations could develop support through intermediary mechanisms. For example, women scientists need to access industry, and technology transfer offices can play an important role in female technology entrepreneurship.
- Female scientists who get mentoring and training about technology commercialization in the early stages of their career would probably attempt to access and build larger industry networks and consider becoming entrepreneurs. There is need to supply mentoring and training for entrepreneurship.
- Programs need to systematically address structural and organisational gender bias in STEM in the tertiary education sector through monitoring of institutional policy, processes and

outcomes by gender. For example, Athena SWAN follows policies specific to recruitment and career progression by gender; monitors access to nationally competitive research funding by gender of investigators with the aim of uncovering informal and formal barriers to gender equity and inclusion.

- Cultural changes in the workplace is necessary for education as well as career building. As shown in the Athena SWAN pilot and other targeted sectoral workplace culture programs, support for proactive changes to cultures of bias reduces gender parity. An important consideration of the Athena SWAN program into the next cycle will be the intersectional relationship between cultural background and gendered progression, and in an Australian context, strategies to ensure a positive model of Indigenous STEM workforce engagement are a priority.
- Organizations must consider increasing women representation at senior levels. Having women scientists at senior levels will challenge the dominant masculine culture and both directly and indirectly increase women representation in organizations. This is also true for entrepreneurial ventures.

<b> **5.2 Limitations**

This study is not without its flaws but we consider it a preliminary work to scratch the surface and catch the attention of researchers in the examination of how institutions influence STEM education and their long-lasting impact on women technology entrepreneurs in Australia and beyond. There are four key limitations. First, our analysis derives mainly from macro-level data in Australia and there are some limitations. For example, data about female high-technology entrepreneurship is almost non-existent. Secondly, considering that SAGE started in 2015, its full impact is yet to come and outcomes are currently immature. Third, the study covers only Australia as a case study. Having one country with a unique cultural setting constrains the generalisability of our findings. It would be beneficial to have more studies from other countries in order to enrich the observation of the dynamics at play. Fourth, this study has not taken into consideration individual or cultural-level factors that could also influence the number of women choosing to become entrepreneurs in high technology ventures. Additionally, there might also be significant organizational factors women interact with in a number of ways. This could be a fruitful research topic for future studies.

<b> **5.3 Suggestions for future research**

In line with the findings of Dilli and Westerhuis (2018), educational institutions have critical roles in supporting not only education but also the career choices of students in the long term, and their inclinations towards becoming entrepreneurs. Given the variety of institutional differences across countries, it would be valuable to pursue cross-cultural studies to identify different programs and policies designed to overcome institutional barriers for women. In particular, it seems the Australian study shows a centralized and proactive effort in diffusing gender equity in Australian universities, through SAGE. There is a significant improvement opportunity with respect to the education of women in STEM fields.

However, the improvement is not yet satisfactory in employment participation in certain sectors with STEM degrees and still low levels of participation in high technology ventures, and it is unfortunately failing to result in senior female positions across sectors. Therefore, even though a higher ratio of women in STEM education could positively influence the likelihood of women becoming technology, science entrepreneurs, future studies could more deeply investigate the question of what kind of institutional policies and programs could facilitate the smooth progression of women graduates from higher education into careers in STEM fields, in particular, becoming entrepreneurs. As the study of Bergman et al. (2018) shows, researchers need to find out ways of changing institutional environments to foster and accommodate female entrepreneurs. In academia, progress might be reflected in having a higher ratio of women in STEM employment and securing senior positions for women.

Additionally, further studies might consider combining individual, organizational, and societal factors in a comprehensive framework and start to observe their complex interactions as mentioned above. That is why a micro-level analysis of women technology entrepreneurs in-depth, through surveys and interviews, would be desirable for a thorough investigation that could help to generate pervasive conclusions. Only then could academic research start to deliver a more-informed line of enquiry, to establish whether organizational factors might overcome societal and/or individual limitations on women in STEM or vice versa.

We hope this paper draws the attention of colleagues interested in these topics and their future exploration.

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