WESTERN SYDNEY
UNIVERSITY

THE UNCONVENTIONAL STRENGTH TOWARDS STEM COHORT

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With respect for Aboriginal cultural protocol and out of recognition that our campuses occupy their traditional lands, WSU acknowledges the Darug, Eora, Dharawal and Wiradjuri peoples. We thank them for their support of our work in their lands.

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EXECUTIVE SUMMARY

Science, Technology, Engineering and Mathematics (STEM) play a critically important role in Australia's ability to innovate, expand and remain a competitive force globally. Indeed, ensuring that the workforce has the relevant skills in sufficient quantities through a reliable educational pipeline is quite challenging and requires an understanding of how these skills are and will be used within the Australian economy. Moreover, successfully delivering these skills for a knowledge economy will depend not only on producing the correct number of graduates but also on the education system supplying graduates from under-utilised groups (i.e. women & indigenous people) and diverse backgrounds.

Currently, millions of children and young people are not developing the required skills to participate effectively in STEM environments. Young indigenous and female groups, in particular, are deprived of the opportunities to build their skills, including STEM literacy that is valued towards career progression in traditionally male-dominated fields (i.e. engineering and construction). As this white paper outlines, the challenges are drawn from recent literature, and a comprehensive review of existing initiatives is presented based on the observations of key partners, including Western Sydney University, the Australian government, research sector, industry, policymakers and communities. However, to build the STEM capacity of graduates with the right knowledge, competencies and qualities, two-way collaboration between the communities, educational institutions (from an early age), Australian workplaces and the government is essential, as no single sector can entirely solve the current STEM skills shortage.

Western Sydney University is well-positioned within the high-density indigenous areas to respond to these issues, particularly by monitoring, engaging and promoting all graduates with STEM qualifications to meet the demand from the economy. In fact, by supporting equity and diversity throughout the STEM cohorts, educational institutions not only drive innovation but also establish a thriving STEM-skilled workforce that is fit for the future.

THE CHALLENGE

INTRODUCTION

The women disparity in the Australian STEM cohort is an issue with multiple priorities and challenges. In addition to the biological differences between women and men, most studies recognised the influence of socio-cultural and economic disadvantages on young women's participation and pursuit of STEM education. This includes gender stereotypes and biases that negatively affect women's educational and employment pathways. As this white paper mentions, the problem of gender and diversity equity in STEM cohort is well known and the challenges usually start from a young age, at school level, to result in Australian students not understanding the importance of STEM or STEM career opportunities until it is too late. This is particularly worse for the indigenous people in Australia, representing only around 2.5% of the population, of which 1 in 200 among the working-age group is employed in STEM-related fields. Currently, there is a crucial need to improve these statistics towards closing the gender gap and embracing diversity across minority groups in STEM to achieve innovative and technological progress.

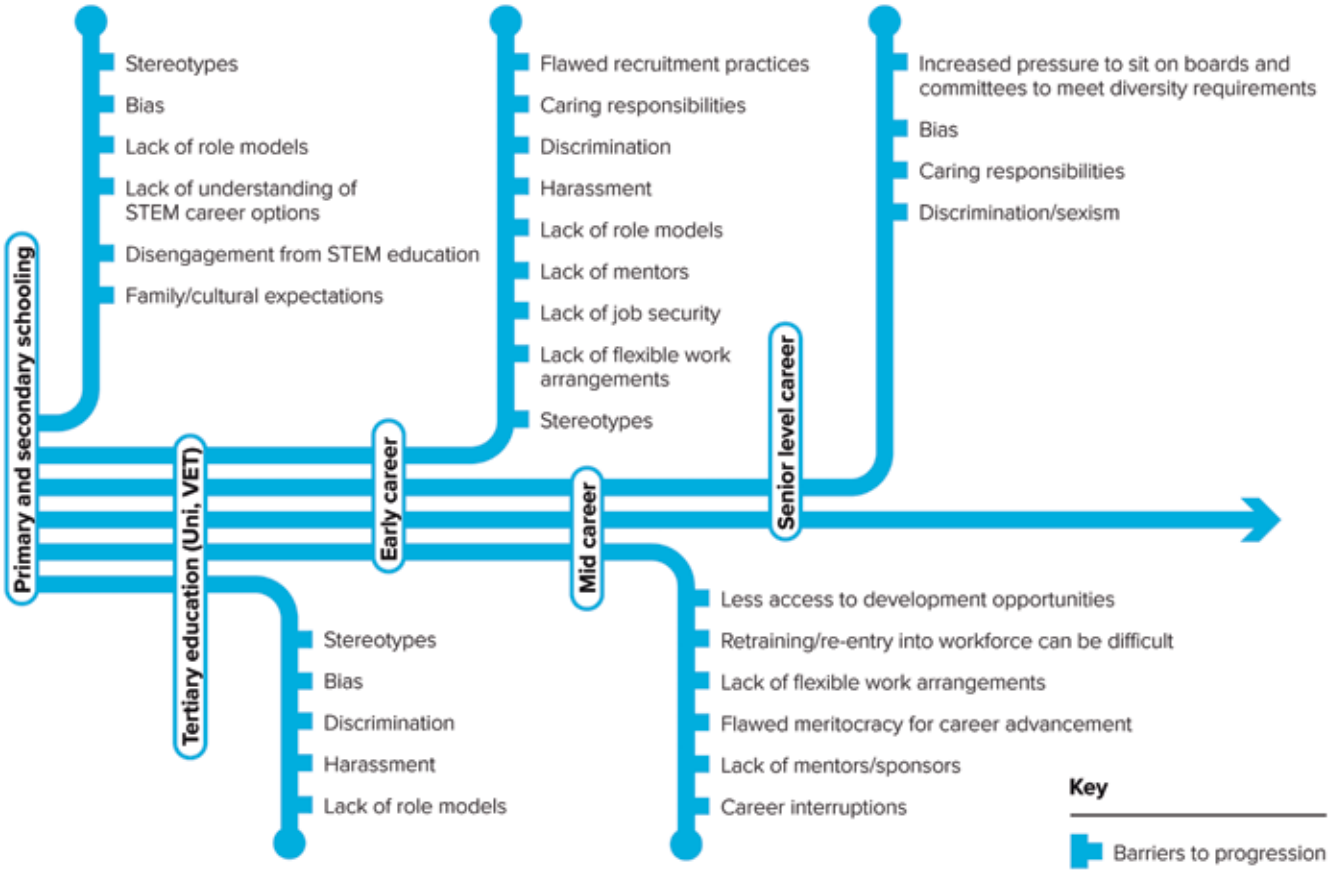

FIGURE 1: Career progression pipeline for women in STEM (Australian Academy of Science 2019)

While the current message delivered to students is the need to study STEM subjects, it is critical to provide context around the STEM skills as a foundation for innovative thinking and real-world problem solving that will drive Australia's productivity and economic growth. Therefore, this white paper aims to highlight the significant challenges associated with STEM's gender and diversity, including the limitation of current approaches (i.e. educational & workplace) that can be translated and scaled to enhance the participation, engagement and representation of young indigenous and female students in Western Sydney and beyond. An overview of the current practices in Australia and around the world demonstrates how participation from a young age, integrated educational and flexible career pathways are crucial to removing barriers at every point of the STEM pipeline (see Figure 1). One of the main gaps highlighted by this white paper was the relative lack of performance data available for educational and outreach programs, preventing effective decision-making and investment.

Moreover, many issues identified as part of the literature were also consistent with the key findings of this white paper. These included but were not limited to the importance of role models, access to career development and reducing cultural stereotypes bias to engage with more young indigenous girls in STEM. Although some schools are currently advocating for these STEM values, the urgent need is to scale up the initiatives to reach more people, especially within remote areas.

Gender equity and culturally responsive environments do not just happen. In fact, they are outcomes of the interaction between individual and corporate ideas, entrepreneurship, risk-taking and investment, and government policies to foster various factors and address barriers to workforce participation. Therefore, building Australia's STEM capability must be an indispensable element of the government's workforce equity strategy, especially since supporting more women into the workforce could add up to $25 billion to Australia's gross domestic product.

GENDER DIVERSITY IN EDUCATION

With the future of work is changing towards a digital environment, existing jobs are being modified and new ones are emerging at the frontiers of developing industries. Indeed, these new opportunities require knowledge and skills in science, technology, engineering and maths (STEM), which workers are expected to possess within their employability competencies. Moreover, STEM awareness is essential for any job as most industries are more or less connected to science and technology and require lateral thinking, problem-solving and innovating skills. In fact, employers agreed that people with STEM qualifications are valuable to the workplace, even when their qualification is not a prerequisite for the role. However, millions of children and young people are not developing these fundamental skills required to engage effectively in a competitive society. In particular, girls are missing the skills they will need throughout their lives and to become more effective citizens and change makers — skills that quality STEM education can cultivate to transform society with innovation and sustainable solutions (Alam & Tapia 2020).

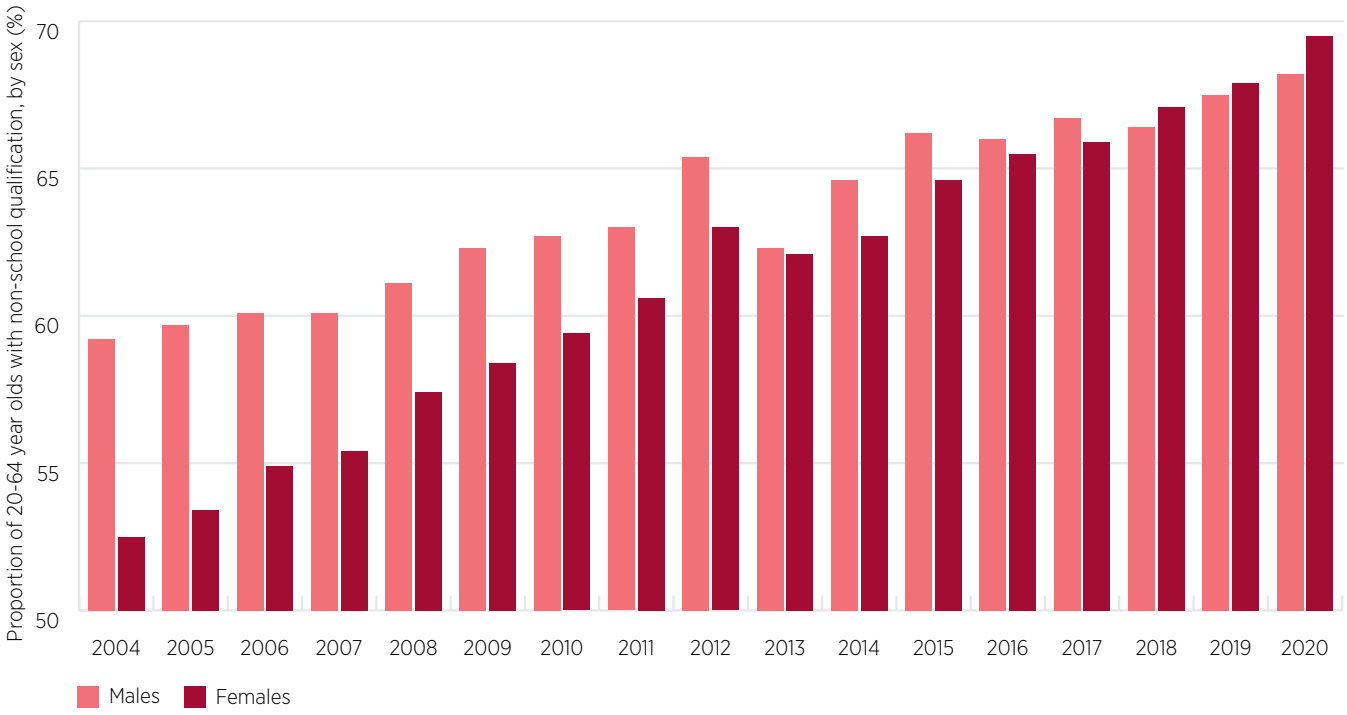

FIGURE 2: Proportion of 20-64 year olds with non-school qualification, by gender, from 2002-2020 (Australian Bureau of Statistics 2020)

While the proportion of females aged within 20-64 that possessed non-school qualifications (i.e. a certificate, diploma or degree) increased substantially over the years (see Figure 2), gender disparity of workforce in STEM fields still exists with on average 82% being males and 19% females, as reported in 2016 (Australian Bureau of Statistics 2020; Leigh et al. 2020). Although women were more likely to have qualifications at bachelor degree or above (39% compared with 31%, refer to Figure 3), the main field of study of their highest qualification was management and commerce (26%), followed by society and culture (20%). The level of qualifications differed for men, with a majority (35%) more likely pursuing vocational education and training (VET) qualifications (i.e. certificate, diploma or advanced diploma). However, the main field of study for men aged 15-74 years was engineering and related technologies (30%), followed by management and commerce (20%), as shown in Figure 4. Despite the number of females with STEM qualifications in the labour force increased by 44% on average (VET-STEM: 14% & university-STEM: 74%) between 2006 and 2016, the proportion of women relative to men still represents a minority (see Figure 5). Therefore, the underrepresentation of females in STEM is not simply because of an overall lower number of females with non-school qualifications; instead, females are less likely than males to pursue study in STEM fields.

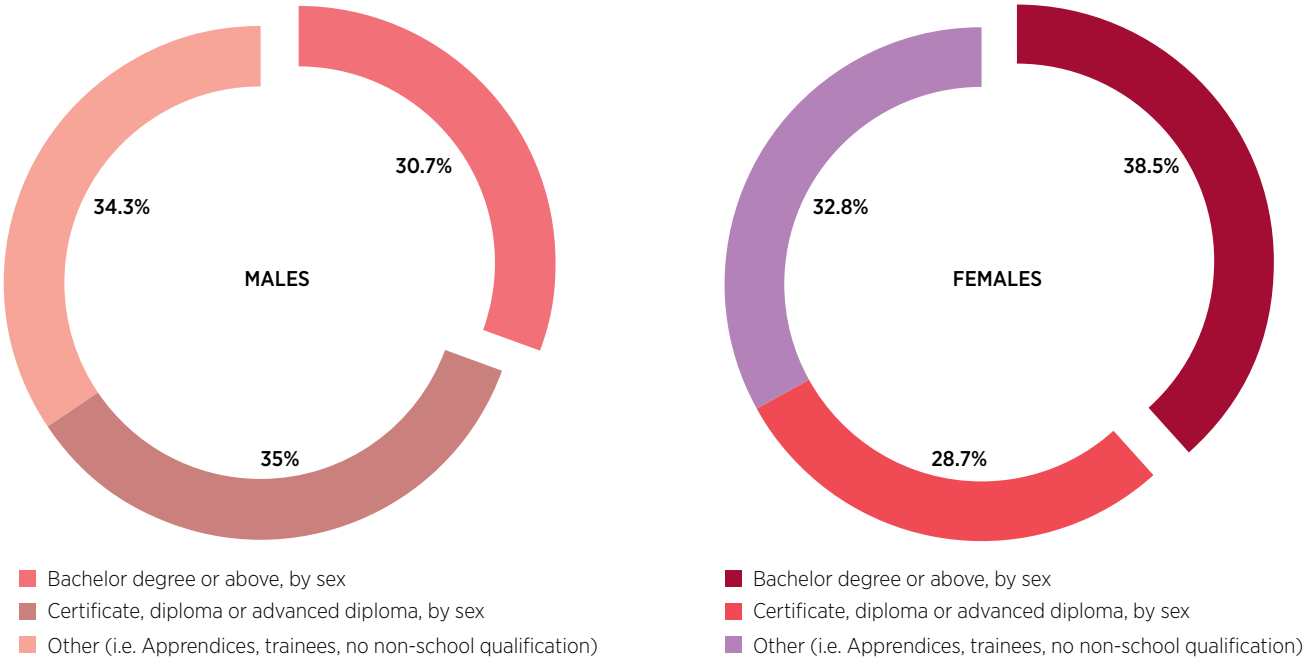

FIGURE 3: Qualifications attainment by level and gender for all persons aged 20-64 years (Australian Bureau of Statistics 2020)

As illustrated in Figure 5, women outnumbered men in non-STEM fields, making up 57% and 61% of the VET and university qualified non-STEM labour force, respectively. While leading Nordic countries like Iceland, Finland and Norway have nearly closed their gender gap on educational attainment, the challenge remains to improve women's participation and enrolment in STEM fields (World Economic Forum 2021). A similar trend is observed globally, with women more likely to be enrolled in higher levels of education than men, yet pursuing non-STEM qualifications for career advancement. Paradoxically, leading countries in gender-equality rankings have the largest gender gap in university STEM qualifications as a result of the high level of social security for all its citizens, which allow women the freedom to pursue other alternatives (Stoet & Geary 2018). Conversely, less gender-equal countries have less secure and more difficult social conditions that may influence women to pursue relatively high-paying STEM occupations towards financial freedom. Although the gender disparity in STEM fields may clearly be influenced by biological, geographical, social and environmental factors, it is essential to promote and improve gender equality across STEM qualifications. In particular, remote communities and developing countries where the male stereotype of science is persistent and may appears as early as kindergarten age to influence potentially the girls' confidence in their STEM abilities and the likelihood of choosing a STEM major at university.

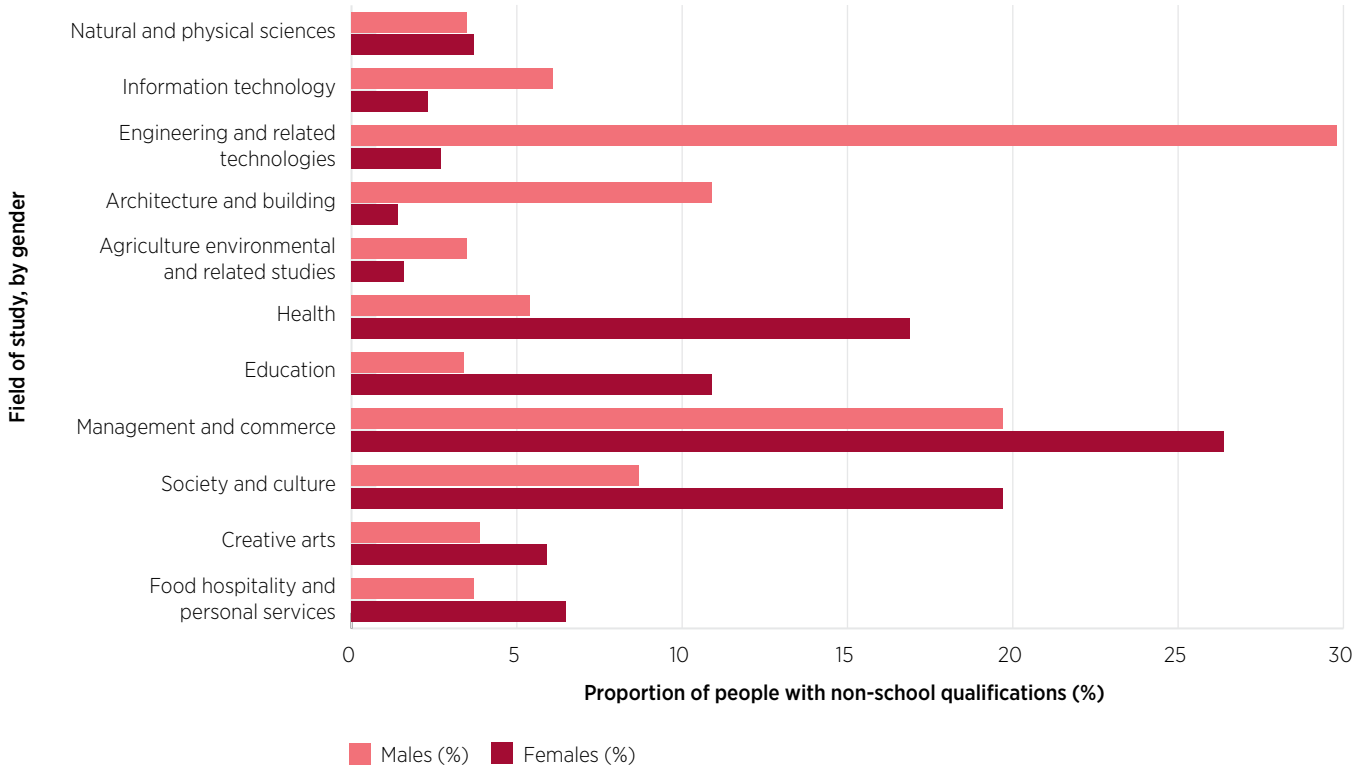

FIGURE 4: Field of study of highest non-school qualification, by gender (Australian Bureau of Statistics 2020)

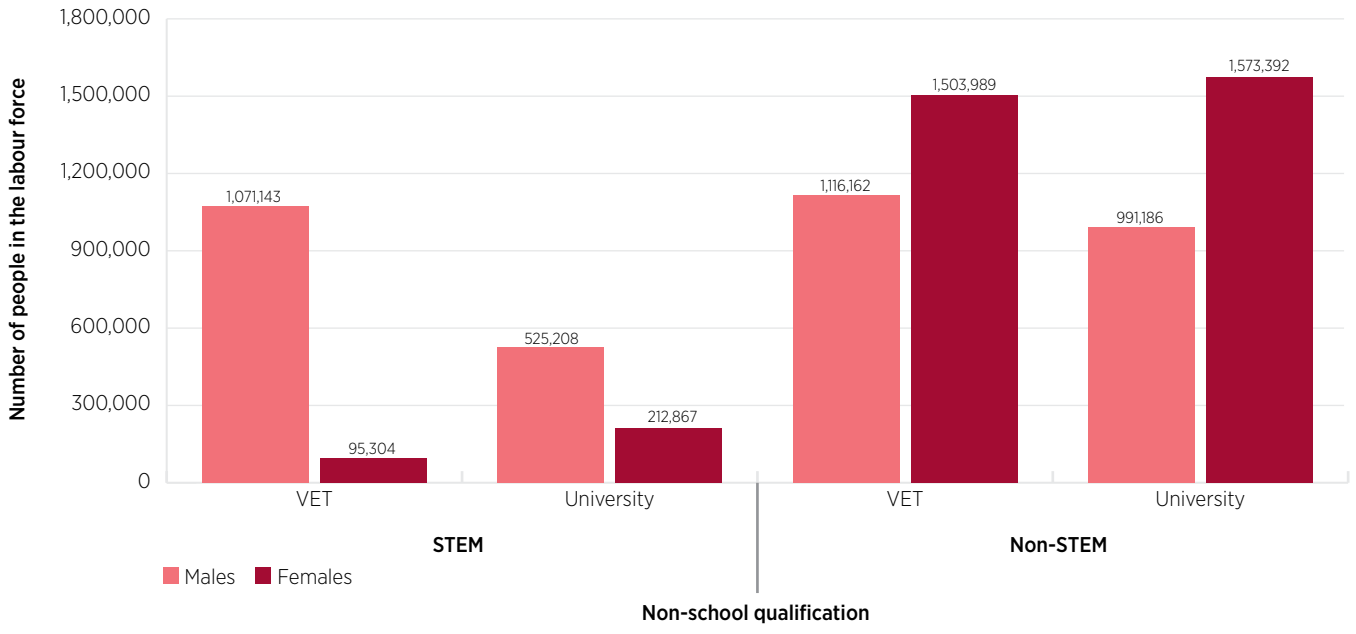

FIGURE 5: Gender distribution of STEM and non-STEM qualified labour force (Leigh et al. 2020)

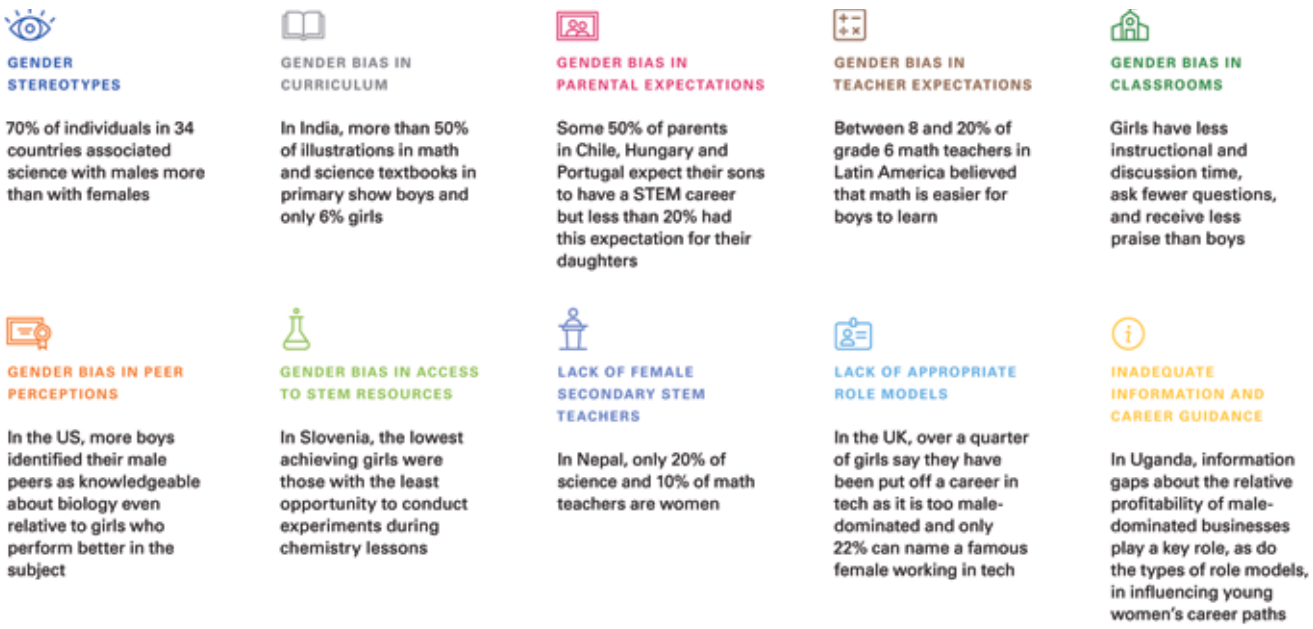

FIGURE 6: Typical gender norms, bias and stereotypes (Alam & Tapia 2020)

Researchers suggested that while women value scientific approaches to enquiry at least as much as men, they have a lower interest in science (except health) and lower participation in science activities in most countries because of gender norms, bias and stereotypes (Alam & Tapia 2020; Cheryan, Master & Meltzoff 2015; Holmes et al. 2018; Makarova, Aeschlimann & Herzog 2019). According to Alam and Tapia (2020), the key attitudes presented in Figure 6 tend to influence the girls' STEM engagement, interest, enjoyment and future career aspirations. Therefore, the exclusion of girls from STEM education is commonly associated with gender gaps that begins at early age and compound over their lifetime.

The exclusion is even more prevalent in minority groups such as indigenous girls who faced additional challenges with socio-economic (i.e. low-income, low levels of parental education), demographical and cultural constraints, preventing access to STEM resources and schools. For instance, families may prefer girls to remain at home and perform domestic duties, while others are reluctant to pursue higher education, as it is not beneficial or productive. Accordingly, such ongoing trends have led to serious consequences for the community and society, with indigenous girls and women often considered as 'third class' citizens because of an inferior status relative to men and to non-indigenous people (Office of the Special Adviser on Gender Issues and the Advancement of Women and the Division for the Advancement of Women 2010). Despite such a trend evolving in recent years with the number of indigenous students' enrolment considerably growing (Figure 7) because of the presence of outstanding indigenous role models, indigenous females' engagement in STEM education continued to be marginal compared with indigenous males. In fact, indigenous women are more likely to enrol in non-school qualifications yet prefer non-STEM fields of study such as health, society and culture. This trend is comparable to non-indigenous female students that reported to have lower interest in science activities because of stereotypes through gender disparity, cultural environment and the media. While the application of gender equality in indigenous people's STEM education may improve the lives and opportunities of indigenous women, it is important to acknowledge their gender-specific role (i.e. ritual, social & economic responsibilities) within communities to prevent other forms of discrimination or inequalities. This is particularly true for existing public policies (i.e. laws, regulatory measures & mechanisms) that may not adequately address the issues of systemic disadvantages concerning gender and indigenous peoples' education. Therefore, the various measures that will challenge the effective participation of indigenous women in STEM must be implemented and monitored at an early age and adopted through national legislation, as discussed in the following section.

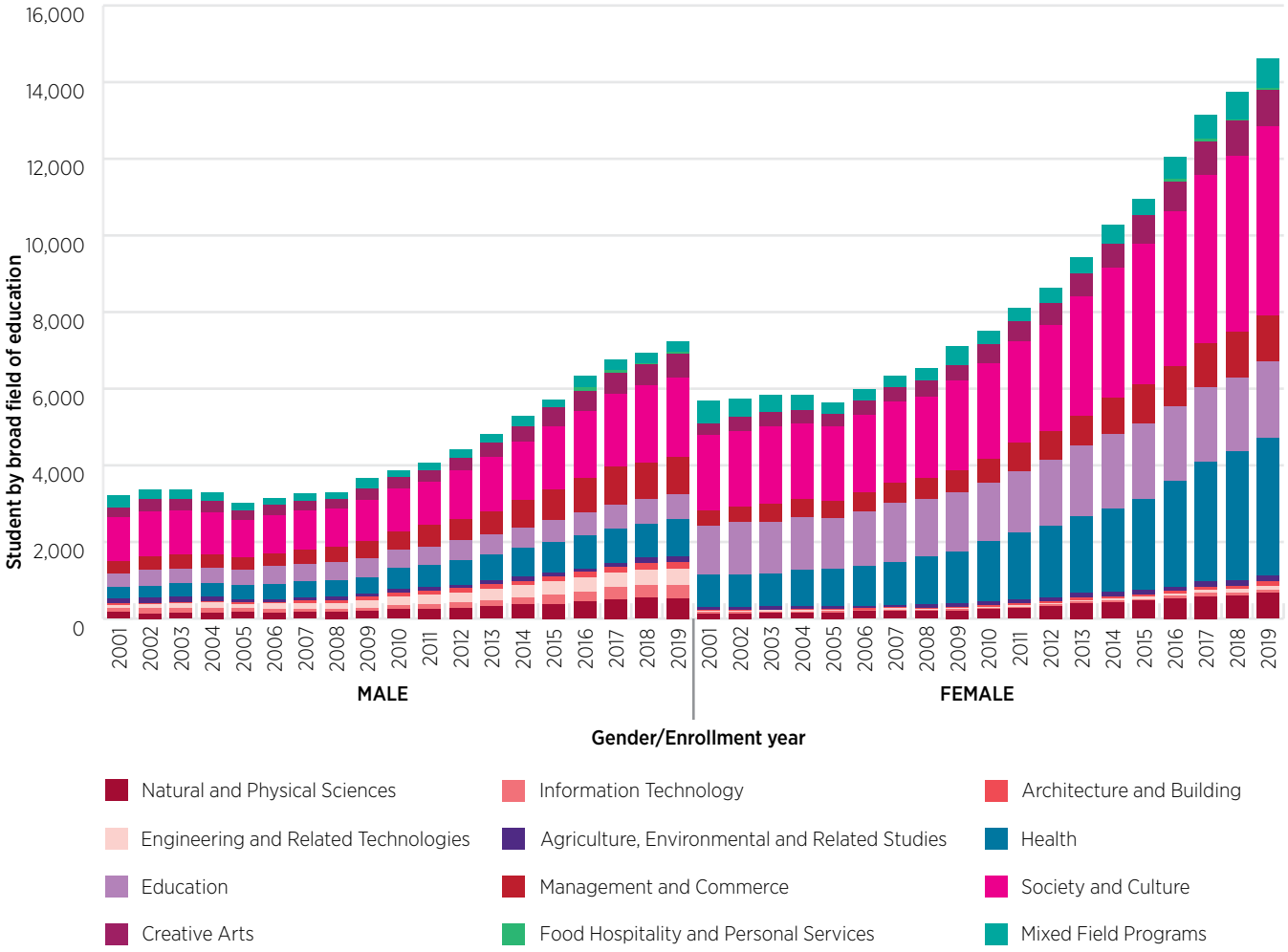

FIGURE 7: Students enrolments by broad field of education and gender for indigenous students (Australian Government 2019)

STEM IN THE WORKPLACE

Australians with STEM qualifications are working across the economy, from education to health, construction, and research to solve the current and future generations' needs. However, as the STEM qualified workforce as a whole is ageing, there is a clear current and future need for STEM skills that STEM education can and will deliver. In particular, with digitalisation and automation evolving rapidly to change the nature of work, digital literacy and flexibility to adapt and embrace new challenges are essential skills as the graduates' careers unfold. In fact, it is projected that future workers will spend 77% more time on job tasks requiring STEM skills (i.e. critical thinking) than today (Australian Academy of Science 2019; Australian Government 2021). Expectedly STEM skills are already in high demand and growing at 1.5 times faster than other jobs. Therefore, to maintain and further develop a prosperous economy, Australia needs to meet these skills demands through an appropriately qualified population that supports inclusive and diverse environments. Indeed, this is crucial for Australia's economy to advance, as diversity (i.e. gender & culture) in STEM broadens viewpoints and allows greater potential for innovation (Ortman & Osborn 2020).

Although the issues of gender disparity and underrepresentation of minorities in STEM start from a young age, comparable systemic barriers persist in the workplace to limit interests, employment and retention in STEM careers (Engineers Australia 2018). Consequently, in 2016, only about 8% and 29% of people with VET and university STEM qualifications, respectively, in the labour force were females (see Figure 5). In 2019, these numbers slightly decreased, with women representing around 16% of Australia's STEM-qualified workforce, despite women accounting for nearly half (i.e. 47.5%) of Australia's total workforce. The lack of gender and cultural equity within STEM is apparent, with the most common driving forces behind women and minorities' (i.e. indigenous people) underrepresentation being:

- → Lower average wages compared to men for equivalent full-time work,
- → Lack of workplace flexibility (i.e. caring for children) and accessibility (i.e. women' toileting/breastfeeding facilities),
- → Career interruptions that include insufficient recognition of part-time work,
- → Toxic workplace culture that includes, but is not limited to, any form of bullying, harassment or exclusion,
- → Bias, discrimination and flawed recruitment methods/criteria used to assess suitability for recruitment, progression and recognition,
- → Lack of role models and visibility in STEM that public representation is portrayed predominantly as male-dominated

(Australian Academy of Science 2019; Australian Human Rights Commission 2020; Leigh et al. 2020; National Academies of Sciences & Medicine 2018).

The following barriers were discussed further as they are currently having a significant impact on women's and girls' participation in STEM workplace and careers in Australia:

Income distribution: Figure 8 and Figure 9 illustrate the noticeable pay gap between men and women workers (i.e. STEM & non-STEM) despite women being highly educated, more likely to graduate and the workplace implementing legislative towards gender equity. On average, higher percentages of women (relative to men) with VET and university qualifications earned an income in all brackets below $65,000 and $104,000, respectively. However, higher percentages of men (relative to women) with VET and university qualifications earned an income in all brackets of $65,000+ and $104,000+ respectively. In general, the distributions of income show that qualified women working full-time earn less than equally qualified men, despite STEM careers offering better salaries than non-STEM fields.

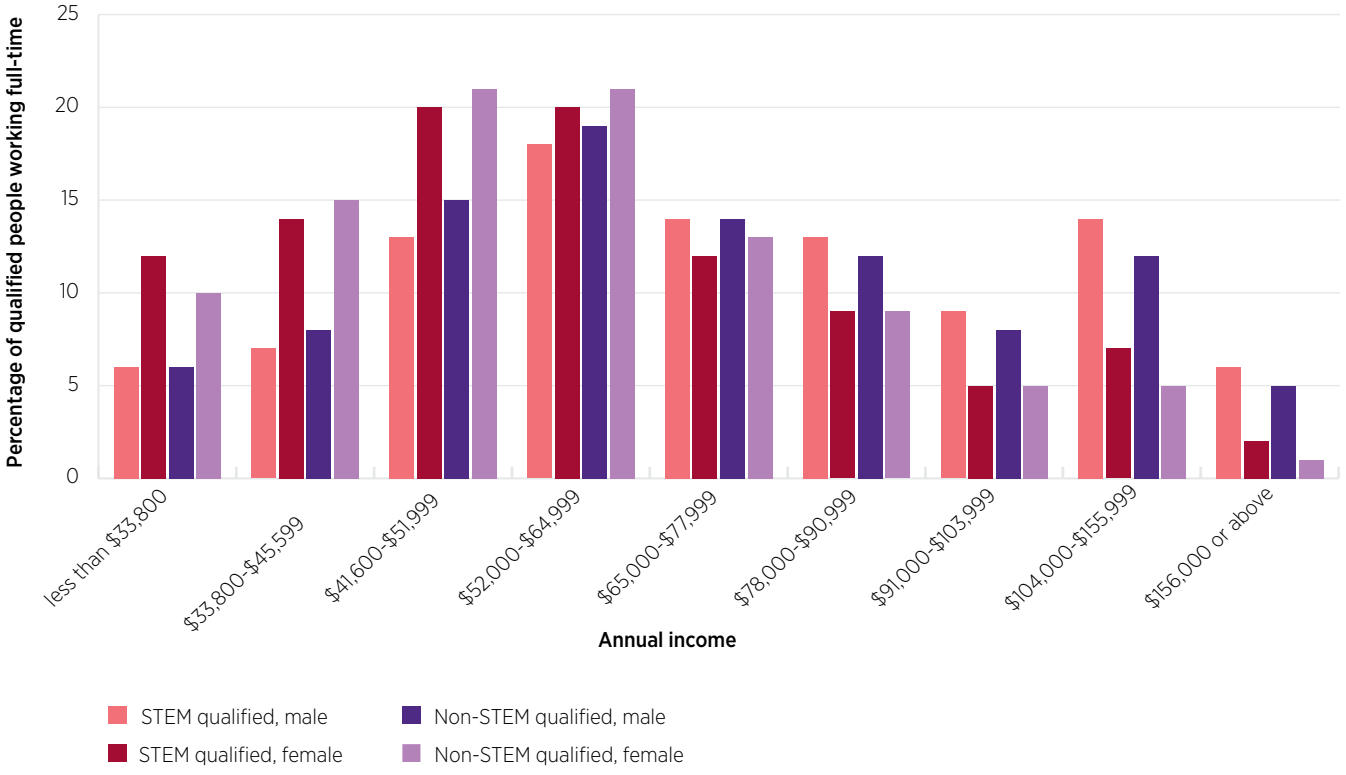

FIGURE 8: Income distribution of full-time workers with VET qualifications, by field and gender

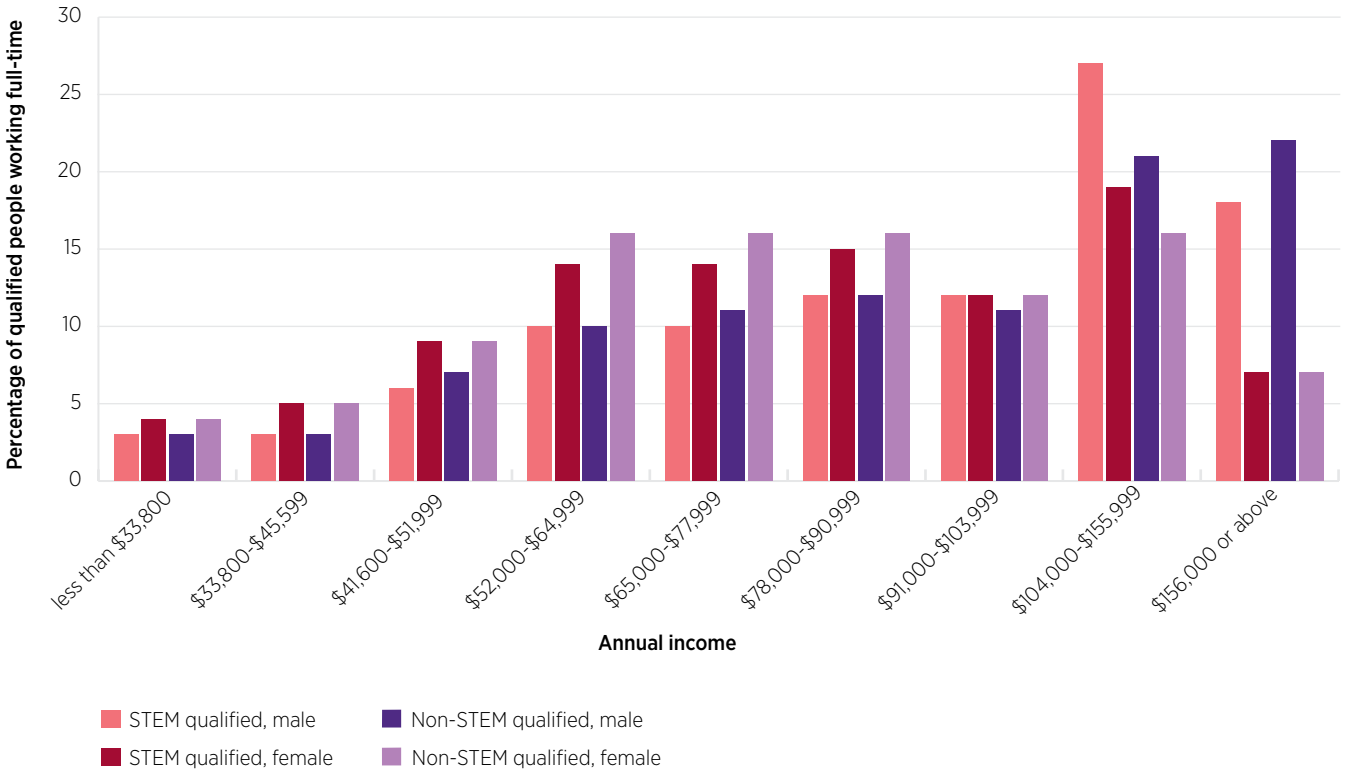

FIGURE 9: Income distribution of full-time workers with university qualifications, by field and gender

Childcare & flexible work: Caring for children is commonly associated with decreased labour force participation and lower average income for STEM qualified women. However, the opposite trend is observed for STEM qualified men with children, often earning more than those without children, while their workforce participation remains relatively unaffected regardless of childcare responsibilities. To present an overall comparison, the employment trajectories for males (with and without childcare responsibilities) with STEM qualifications were comparable to the pathways of equally qualified women without children. However, for STEM-qualified women who had given birth to one or more children, a considerable proportion (see Figure 10) preferred to undertake part-time work or ultimately left the labour force.

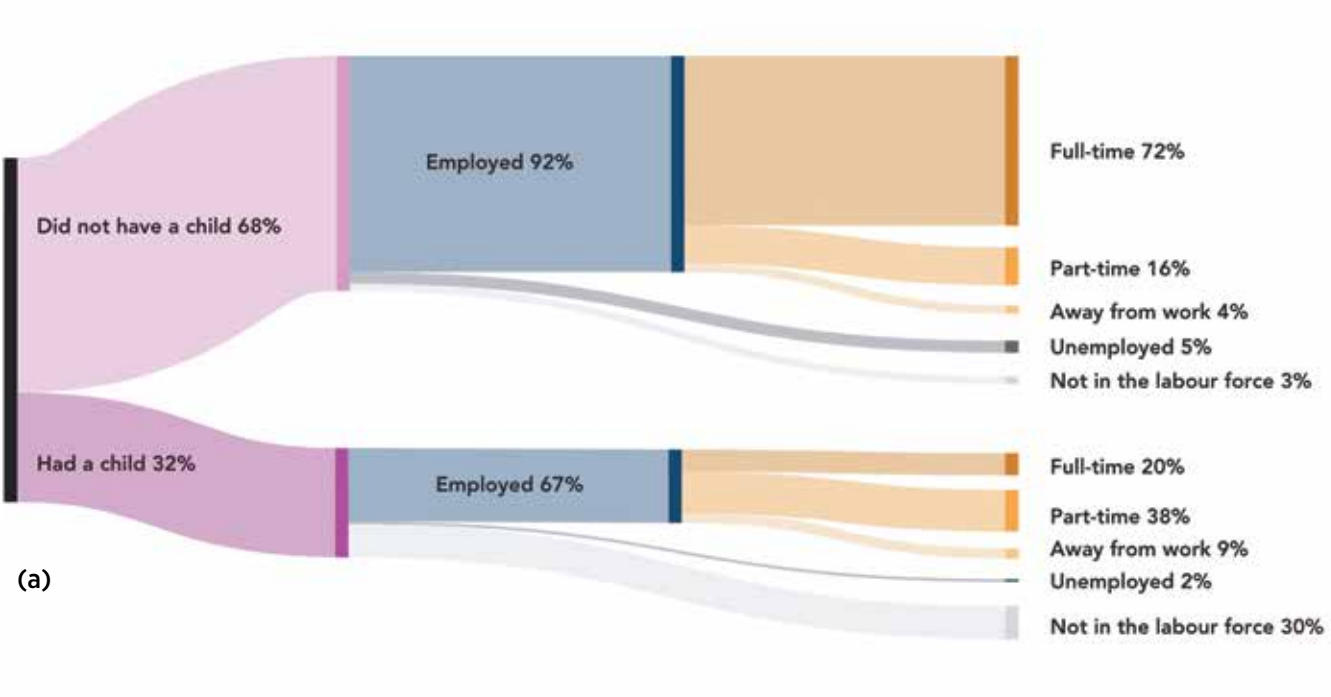

FIGURE 10: Employment pathways for females with STEM qualifications aged – (a) vet STEM and (b) university STEM (Leigh et al. 2020).

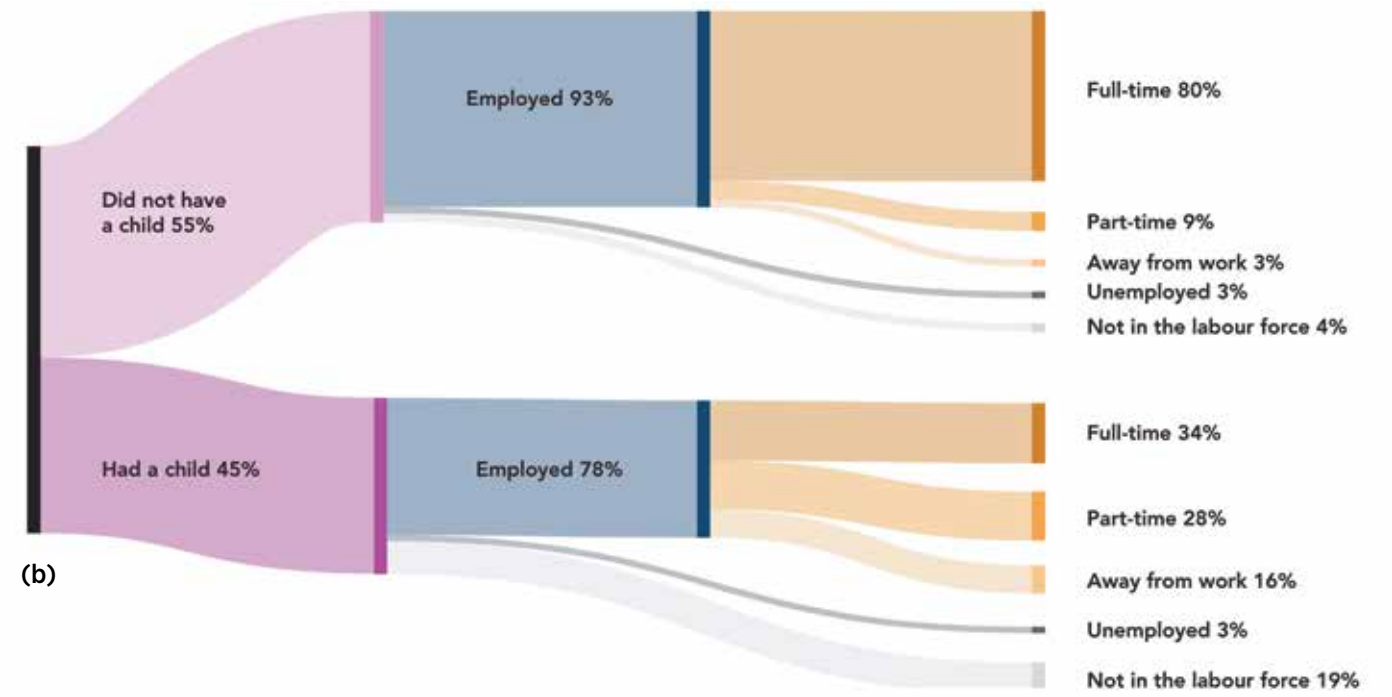

FIGURE 10: Employment pathways for females with STEM qualifications aged – (a) vet STEM and (b) university STEM (Leigh et al. 2020).

Bias, discrimination and flawed criteria: The recruitment, progression and recognition methods within the workplace are considered as having a significant impact on women and minorities representation in STEM. Indeed, women and indigenous people face additional systemic challenges that typically result in higher unemployment rates than men and non-indigenous people, respectively.

Clearly, there is a considerable need to put into place more policies and programs that encourage, support women and indigenous people in STEM careers, and remove systemic barriers to their advancement, since it has been suggested that reducing the gender participation gap by 3% could add up to $25 billion to the Australian economy (Commonwealth of Australia 2017). In the same mindset, shifting just 1% of Australia's workforce into STEM jobs has the potential to add $57.4 billion to the nation's GDP over 20 years. Such financial incentives could be particularly valuable to the Australian economy following the devastating impacts of bushfires and Covid-19 in the last few years, during which the STEM workforce has shown considerable importance in developing solutions for response, recovery and long-term resilience. However, these events have also exacerbated pre-existing inequity and raised new barriers in attracting, retaining and progressing women through the STEM workforce (Australian Academy of Science 2021). For instance, while both men and women were severely affected by the pandemic, women experienced a larger impact through reduced working hours and labour participation as a result of childcare responsibilities that still rely

predominantly on them (World Economic Forum 2021). In addition, through lockdown disruptions and social distancing measures, young women consequently experienced higher unemployment as well as slower re-employment (i.e. lower & delayed hiring in leadership roles) rates relative to that of men at the start of the pandemic. The main challenges emerged from the evidence that women in the STEM workforce were facing during the pandemic are as follows:

- For most people, the new lifestyle of working from home challenged the spheres and boundaries of work and home. Although both men and women reported spending more time at home (men: 61% & women: 63%), more women experienced increased housework and additional caring responsibilities (i.e. school-aged children & elderly relatives). Combined with an increased workload, 30% of women reported decreased productivity and 12% decreased income. Conversely, men in the STEM workforce were less likely to report changes in increased workload, decreased productivity and income (Australian Academy of Science 2021).
- More women than men in the STEM workforce are at early or mid-career stages (i.e. junior roles) while being under-represented at senior levels. Consequently, women in STEM tend to have less secure employment and are more susceptible to job loss due to the pandemic. Such a trend also applied to non-STEM fields where more women (53%) have seen their work hours reduced compared to men (31%), as reported by the UN Women Regional Office for Asia and the Pacific (2020). However, of those women planning to stay in STEM workforce, the majority reported motives because of personal passion rather than work fulfilment, while those considering leaving, these were due to lack of job opportunities (35%), job security (25%) and family responsibilities (22%).

For the STEM ecosystem to recover and respond actively towards future needs, individuals, organisations, communities, and governments each need to play a part in supporting women in STEM to navigate challenged work-life boundaries that the pandemic has worsened. Accordingly, the following actions are identified to retain and improve the participation of women from an indigenous and non-indigenous backgrounds in the STEM workforce:

- Normalise flexible work practices (i.e. work hours & workspace), making them available to all genders.
- Provide accessible and affordable quality childcare and early learning support. Moreover, it is critical to provide adequate paid parental leave for all parents, regardless of gender.
- Retain and enhance existing diversity and inclusion strategies towards developing inclusive workplace cultures.

Since the expertise needed to address these issues does not develop overnight, planned strategies with systematic understanding and awareness of the STEM ecosystem is required to build the workforce for the future.

BEST PRACTICE

WOMEN AND INDIGENOUS PROGRAMS

Although the status of indigenous women varies from one community to another, the challenges they face throughout the world and in Australia are similar because of their indigenous status. To overcome these experiences and challenges (i.e. lack of access to education, socio-economic development), most studies suggested the importance of prior achievements and awareness in STEM from a young age to facilitate STEM career development and aspirations. (Holmes et al. 2018; Shapka, Domene & Keating 2006). Accordingly, various educational initiatives invested substantial amounts of money in supporting indigenous women and girls in Australia to pursue education and careers in STEM professions. While different organisations and programs for related supports (i.e. qualified teachers, evaluation & reporting tools) may share the funding, their aims remain to engage, inspire and break down barriers for girls and women getting into STEM education and careers.

CSIRO EDUCATION AND OUTREACH PROGRAMS

The Indigenous STEM Education Project is a six-year initiative funded by BHP foundation and implemented by CSIRO across Australian states. It comprises of six program elements that cumulatively; develop educators' competency to engage all students (regardless of their cultural backgrounds: indigenous & non-indigenous) students in STEM studies, support indigenous students to pursue their passion for STEM at tertiary level and promote STEM role models to encourage the next generation of indigenous students. Although the six different programs are independent, they have a common set of principles that account for strengths (i.e. skills & knowledge of communities), high expectations, STEM pedagogies and flexibility, with considerations to cultural barriers (Walker & Banks 2021). Table 1 summarises the key objectives, delivery models and outcomes of the six initiatives encompassed within the Indigenous STEM Education Project.

Accordingly, the Indigenous STEM Education Project represented an ambitious initiative aimed at increasing interest, engagement and academic achievement among the indigenous students and related professions. Although 2021 marked the conclusion of the programs, key resources remain available to support both teachers and schools in developing cultural awareness, inquiry-based science and culturally responsive teaching approaches. Figure 11 presents the overall achievement throughout the six years of the Indigenous STEM Education Project that influenced over 23,904 indigenous students, 2,768 teachers and assistant teachers, and 603 schools. Based on a similar transformative-effective-emerging scale used to assess the individual program (not discussed herein), the overall results reported considerable improvement (i.e. transformative) in some outcomes and less (i.e. emerging) in others.

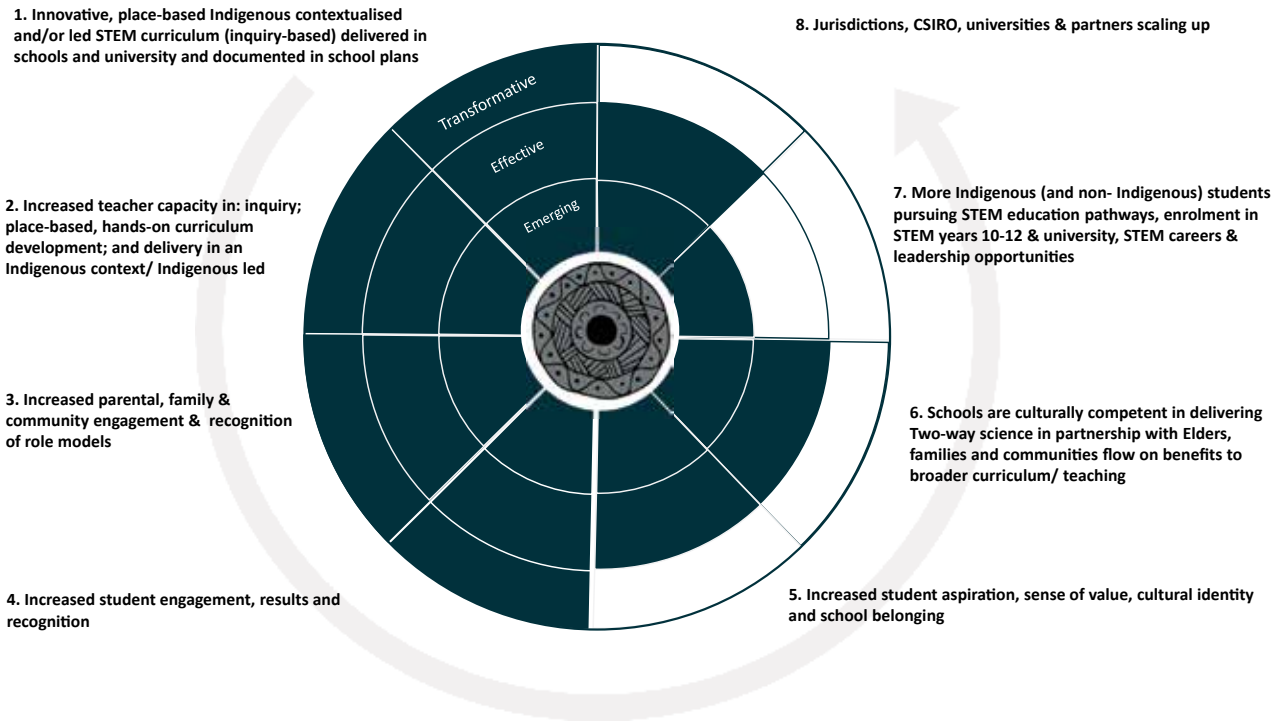

FIGURE 11: Impact achievement of outcomes for the Indigenous STEM education project (Walker & Banks 2021)

Accordingly, some essential lessons were learned from the Indigenous STEM Education Project towards providing recommendations for the success of ongoing or future indigenous STEM programs. These key lessons and recommendations are as follows:

1)	Online environment increases program reach and access for many teachers and schools, yet at the cost of relationships and development of a community. Where possible, face-to-face interactions between program teams and educators should be included in all programs to reinforce and strengthen relationships and build personal connections and trust.
2)	Programs working to facilitate lasting, systems-level change in the education sector should have a strategy to engage with key policy stakeholders and government departments. Moreover, it should establish robust monitoring systems to enable longitudinal tracking of student pathways and, where relevant, results.
3)	Evaluation results from the Indigenous STEM Education Project support research findings indicating that embedding change in school and tertiary environments takes time (5+ years). Therefore, programs should adopt a long-term, realistic horizon for affecting change and work with funding partners to secure necessary resources over that period.

TABLE 1: Summary of the Indigenous STEM Education Project and key outcomes (Tynan & Noon 2017; Walker & Banks 2021)

INITIATIVE	KEY OBJECTIVES	DELIVERY MODEL	SHORT-TERM/INTERMEDIATE OUTCOMES	LONG-TERM OUTCOMES
Aboriginal Summer School for Excellence in Technology and Science (ASSETS)	Provide opportunities to high-achieving year 10 indigenous students, with interests and aspirations in STEM careers	→ Intensive summer school → Ongoing partnerships (i.e. universities & research organisations) providing exposure to cutting-edge research and technology → Integrated and overarching Alumni support and cultural programs	→ A better understanding of and confidence pursuing STEM career pathways → Growth in student and professional networks → Participation in broader STEM initiatives – e.g., work placements, Awards program, CREST, BHP Science Awards, university STEM programs.	→ Continued success in STEM subjects in Years 11-12, particularly direct university entry from ATAR → Students connected with post-secondary internships, cadetships, scholarships, and other unique opportunities.
Bachelor of Science	Provide a supported pathway for indigenous students to complete a Bachelor of Science degree	→ Four-year degree program at the University of Melbourne → During the first three semester, students take a number of integrated STEM subjects	→ Strong student engagement, retention, and results. → Increased student aspiration & students successfully transition into Bachelor of Science.	→ Strong student engagement with development opportunities → Indigenous students succeeding in tertiary education, including graduating from Bachelor of Science
Indigenous STEM Awards	To recognise, reward and celebrate the achievements of indigenous students and scientists that study or work in science	→ Finalists and recipients are selected by a panel comprising of professionals from CSIRO, BHP foundations and other STEM organisations	→ Indigenous STEM achievement and best practice in teaching promoted → Active, engaged, skilled and growing Awards Alumni network	→ Raising student aspirations to pursue STEM education and careers → Increased recognition of the role of family, community and mentors to success in STEM
Inquiry for Indigenous Science Students (I^2S^2)	Provides opportunities for indigenous students in Years 5-9 in metropolitan and regional schools	→ Development of indigenous themed, hands-on science inquiry resources for teachers and schools → Professional development and support for teachers → Recognition of the enduring relationship that indigenous people have with science	→ Teachers adopting inquiry-based pedagogy and improving cultural responsiveness → Increased student engagement, results and aspirations → Increased community and parental engagement	→ Increased number of students (indigenous & non-indigenous) pursuing STEM pathways

INITIATIVE	KEY OBJECTIVES	DELIVERY MODEL	SHORT-TERM/INTERMEDIATE OUTCOMES	LONG-TERM OUTCOMES
PRIME Futures	Contributes to the delivery of maths pedagogy to higher-than-average indigenous student populations	→ Uses the YuMi Deadly Maths approach (YDM) → Focus on increasing teachers' capacity to understand indigenous culture and integrate it into mathematics lessons	→ Positive student engagement with new pedagogy → Improved teacher capacity and capability, delivering culturally responsive maths pedagogy → School classrooms are culturally and socially safe	→ Increasing cohort of students choosing STEM subjects in Years 10 to 12 → Increased teacher and student pride in self, school and community
Science Pathways for Indigenous Communities	Supports remote indigenous communities and schools to improve STEM education outcomes	→ Support selected community schools to develop STEM teaching and learning programs → Engagement with indigenous teachers and elders to identify skills and knowledge required → Training and resources to teachers linking Indigenous ecological knowledge with Western science and the Australian Curriculum.	→ Strong, effective partnerships established. → Increased community and parental engagement → Increased student engagement, attendance and aspirations	→ Enhanced student results → Science learning approach and resources are culturally responsive

Based on the body of evidence about the effectiveness of the Indigenous STEM Education Project, new programs have been developed to invest further in an innovative STEM-skilled workforce. For instance, the Generation STEM initiative that represents a ten-year $25 million endowment made by the New South Wales Government to attract, support, retain and train NSW students into STEM-fields education and employment. As a result of its past experience in delivering STEM education of the highest quality to Australians, CSIRO has been enlisted to deliver the program in Western Sydney region because of a growing need for a STEM-skilled workforce (i.e. Western Sydney Airport & other major developments around the region). Accordingly, both the students and communities are expected to benefit from the programs through:

- → Increased real-world exposure and work-ready students transitioning into the local STEM workforce
- → Enhanced level of youth engagement and connections between school, STEM networks and industries
- → Heightened awareness of local STEM-field career pathways and opportunities

While the Generation STEM initiative aims to broadly attract more diverse and high-potential students into STEM educational pathways, other programs such as the Young Indigenous Women's STEM Academy solely focus on young indigenous women, providing them with long-term support in pursuing STEM careers. Furthermore, as the Academy operates nationally in strategic locations based on populations and language groups, it can provide targeted access to STEM resources for high achieving students and ensure that they are best placed to succeed in their STEM qualification and career. Therefore, through the participation of more young women from traditionally underrepresented groups, the Australian government can promote STEM values, bring more diversity to the workforce and maintain its ability to innovative discoveries.

WOMEN IN STEM AND ENTREPRENEURSHIP (WISE)

Similar to the CSIRO Educational and Outreach programs, the Women in STEM and Entrepreneurship is a Government-funded initiative to improve Australia's competitiveness in STEM and promote gender equity. Since 2017, the WISE program has provided around $10 million in funding for projects across every state and territory in Australia, with the aim to eliminate barriers for women's STEM education and careers. In the latest round of grants, eight organisations, including Engineers Without Borders and the University of Canberra, shared in nearly $2 million to boost representation of women in STEM by:

- → recruiting young women and girls to develop solutions for real STEM and entrepreneurship challenges,
- → enhancing the visibility of successful women of colour entrepreneurs, and delivering education programs to support women and girls of colour to enter STEM studies and careers,
- → promoting engineering as a values-aligned and socio-technical profession to bring more diversity to the workforce,
- → delivering a comprehensive capability-building program to support primary school teachers to engage and inspire young girls in engineering, IT and related digital technologies.

Although the specific objective of each program may vary based on targeted communities, related fields and organisations vision, the intended outcomes of the program remained to increase awareness, participation and opportunities for girls and women in STEM education and career. Moreover, the program aims to provide evidence-based data for future strategies and policies towards improving gender equality in the STEM cohort. Unfortunately, no detailed statistics were available for the impacts and outcomes of the last round of WISE grants at the time of publication. However, it is acknowledged that we must go beyond simply increasing the participation of young women in STEM fields and instead understand the longstanding barriers that women face as they grow up and enter the workforce. These systemic concerns could be addressed effectively through proper diversity and antidiscrimination policies that ensure management accountability and promote a safe STEM environment for young indigenous women.

GOOD PRACTICE IN AUSTRALIA AND AROUND THE WORLD

As reported by the National Indigenous Australians Agency, education is key to increasing the well-being of the indigenous population across all aspects of life. Of particular relevance to the young indigenous women's STEM education plans are; the high expectations philosophy of success from both teachers and students; and a learning environment that is responsive to individual needs. Accordingly, examples of good practices in Australia and around the world that promote strong STEM participation and policy frameworks for minority groups are as follows:

- A national science curriculum taught from foundation to Year 10 across all states and territories in Australia that provides an inquiry-based approach to science using specific contexts relevant to students. Through a model of student engagement and inquiry, students will learn the ways that traditional ecological knowledge and western scientific knowledge could be complementary.
- Primary Connections is a teacher professional learning program that is supported by substantial curriculum resources (with indigenous perspectives) to develop explicit literacies of science through an inquiry-based approach and purposeful activities (Hackling & Prain, cited in Tynan & Noon 2017). As a result of increased teacher's confidence and enjoyment, the students' conceptual understanding, engagement, and performance also benefitted. Bull (cited in Tynan & Noon 2017) further reported improved relationships between the school, parents and the community.
- The National Association of Women in Construction (NAWIC) is an Australian, not-for-profit organisation led by a team of passionate volunteers who strive to help champion and empower women in the construction and related industries to reach their full potential. Active in every state and territory around Australia and part of a global network of NAWIC organisations, including those in the United States, New Zealand, and Canada. By providing a forum for its members to meet and exchange information, ideas and solutions, NAWIC offers the opportunity to expand personal and business networks, maintain awareness of industry developments and improve skills and knowledge to other women in the construction industry.
- The recognition of equal value and status to the Indigenous knowledge alongside Western knowledge in schools, while also providing education in languages that children speak. Since the main entry point for scientific education in remote schools is through Indigenous Land and Culture program (ILC), it is crucial that Indigenous and non-Indigenous teaching staff communicate an interrelated cultural knowledge and practices with strong connections and engagement to the community.
- In some Canadian provinces, the Saskatchewan science curriculum presents a culturally responsive teaching framework that integrates indigenous knowledge into science classes. The cultural knowledge systems include: 1) a scientific system based on an intellectual tradition of thinking and; 2) an indigenous system based on a wisdom tradition of thinking, living and being. As stated by Aikenhead (cited in Tynan & Noon 2017):
  - The two coexist; they are not in competition with each other. All students are expected to understand the best of both ways of knowing nature. But students are not necessarily expected to believe what they understand. Their personal beliefs are personal.

  Through culturally appropriate teaching strategies, assessment and recognition of cultural styles for interpersonal communication, this approach proved successful with an 80% increase in students' enrolments in optional science courses.
- In the USA, strong evidence base for best practices supporting minorities in STEM included; engaged faculty, personal attention through mentoring and tutoring, student peer support across cohorts, disciplines and professions, and a continuous evaluation of support processes and outcomes. Further, culturally-based science curriculums improve students' achievements and engagement, with STEM competencies more likely to be seen as relevant by students to their everyday lives. According to Nelson-Barber (cited in Tynan & Noon 2017), these key developments tend to have smaller STEM class sizes, however, promote persistence and create more supportive environments for the student comfort zones.

The emerging good practices towards developing STEM and Indigenous education reveal a substantial increase in female and indigenous student engagement at university levels. However, more attention is required at school levels in enacting a high expectation philosophy, maintaining strong relationships with the indigenous families and communities, and ongoing funding to implement and monitor the programs effectively until sustainable changes.

CURRENT WSU PROGRAMS & SUCCESS STORIES

While various governmental outreach programs and international practices that support minority groups (i.e. women and/or indigenous peoples) are outlined in Section 3, this section focuses on the current Western Sydney University (WSU) commitments and success stories in promoting STEM values and careers.

Through the 21C initiative, WSU committed to further strategic investment to meet the opportunities and challenges presented by the Job Ready Graduates Package and the post-COVID higher education context. Accordingly, three streams are underway in 2021, focusing on transforming the curriculum, teaching approaches, and innovating the university credentials. Although indirectly or directly related to STEM, most of the programs listed herein are designed to provide opportunities to students and deliver excellence in university teaching and learning (Western Sydney University 2021).

- Badugulang is a 21C initiative to enhance WSU community's capability in delivering transformative and contemporary curriculum and teaching. As the centre was recently launched in July 2021, limited data on the impact and achievement is available. However, the centre for teaching and learning excellence aims to bring together experts teachers, leaders, teaching staff and curriculum partners to share ideas, increase staff recognition for contributions to teaching and strengthen external visibility.
- STEM + Capable is a 21C initiative for transforming STEM curriculum that will future-proof existing degrees with simpler and more flexible pathways. Moreover, it will provide more attractive study choices, the capacity to rapidly develop and deploy new curriculum elements to complement in-degree learning towards improving STEM accessibility and interdisciplinary collaboration. The new curriculum explores eco-socially conscious design, manufacturing and health technologies that use work-integrated learning activities to improve students' employability and their abilities to adapt to the ongoing automation practices in the industry.
- Badanami Centre for Indigenous Education provides a place on each WSU campus for Indigenous students to gain support and connect with staff about their knowledge and experience. Moreover, 'The Pathways to Dreaming' and the 'Australian Indigenous Mentoring Experience (AIME)' are two ongoing mentoring programs offered at WSU through the Badanami Centre that incorporate academic, professional, personal life skills and indigenous cultural enrichment. Mentored by current WSU students, alumni and staff, both programs are designed to actively engage and encourage indigenous high-school students to pursue their educational aspirations.
- Another initiative that raises the aspirations of indigenous students, this time at a much younger age (i.e. primary school students: Year 3 to Year 6), is the WSU's Heartbeat program. The program mainly consists of on-campus visits and in-school presentations each year to raise students' awareness of their well-being, indigenous related health issues and inspire them to consider careers in medicine, health and science. Moreover, as indigenous Elders, staff, students and a range of community and industry partners deliver the program, indigenous cultural support and enrichment are strongly promoted while also closing the gap in educational outcomes.
- The Indigenous Engineering Aspire Program is an internship initiative by Western Sydney University to support the participation in engineering and career development of indigenous engineers. Launched in 2020, the program that forms part of the ongoing university commitment to improving the representation of indigenous people in STEM will connect students with industry partners through internships, mentoring and workplace training. This unique and global initiative also assist students throughout their degree to reach their potential as the next generation of talented indigenous engineers (Sardyga 2020).
- The School of Education initiative for a Master of Teaching Secondary STEM, in which the numbers in the cohort have increased over the two years in which it has run. Currently, the number of students in this program is 24, with pre-service teachers having undergraduate qualifications in mathematics, sciences and engineering (Holmes et al., 2018).
- The school of Engineering's Women of Wisdom (WoW) initiative supports female engineering students through mentoring, assistance with coursework and providing a support network to the industry. Another program is the Women Transforming the Built Environment (WTBE) which focuses on increasing female participation in the Bachelor of Construction Management and Bachelor of Construction Technology, increasing the visibility of professional women and opportunities for students to engage with the industry.

The Women in STEM Education (WiSE) program at Western Sydney University supports the career development of women studying in STEM fields. Since females in the STEM workforces are considerably underrepresented (i.e. ~16% of STEM qualified Australians, see Section 4), WiSE aims to challenge gender disparity in STEM with practical strategies that encourage students to pursue a STEM career. Indeed, by connecting students with peers, alumni and potential employers (i.e. professionals & industry mentors), the young women are empowered to develop their professional skills and become strong role models for other students, providing STEM qualified women with endless career opportunities. The impacts of the WiSE program are as follows:

THY PHAM
BACHELOR OF ENGINEERING (CIVIL), 2012 – 2016

She joined the WiSE program in the final year of her bachelor's degree, following which she was paired with the construction director of Transurban. Through monthly mentoring updates, Thy reported participating in site visits and being encouraged to apply for various job opportunities. With encouragement from her mentor, she was eventually fortunate to land a full-time job in which she is currently employed as a graduate/junior engineer. Thy further stated, "In the past year, I have learnt so many things and have met some really great and supportive professionals in the industry to guide me through the early stages of my career" (Pham 2016).

GEORGIA FREE
BACHELOR OF SCIENCE (ADVANCED) (CHEMISTRY) WITH DISTINCTION, 2015 – 2017

She joined the WiSE program during the first year of her bachelor's degree and has remained an active member throughout her studies. After completing a number of activities related to career planning, researching and future employers, as well as her interest in further study and research, she was paired through the Mentoring Strand to a science professor that provided her with "fantastic study and career advice". Through the WiSE program, Georgia also had the opportunity to gain credit for volunteering in community work that further built her employability skills. Georgia stated that she would recommend mentoring to other students as it provides an opportunity to gain insight into the world beyond their degree with someone to give advice along the way. Currently, Georgie is pursuing her Master of Research degree at WSU, as she wants to run her research team at a university or medical institute in the future (Free 2017).

EMINA MUJANOVIC
BACHELOR OF INFORMATION AND COMMUNICATIONS TECHNOLOGY, 2015 – 2017

She joined the WiSE program during the second year of her bachelor's degree after first finding out about the program through the mail. At the time, she did not really know which direction her degree would take her, and through the WiSE program, she hoped to gain the knowledge, experience and technical/professional skills needed to achieve her career's goals. During her first year in the WiSE program, Emina learned about important career-related platforms that had considerable influence on her job-hunting and networking approaches. As a result, in her final year of study, Emina's career objective clarified where she would prefer to find a job that she loves doing and be surrounded by a good team of people. Now graduated, Emina remains at WSU where she is employed in a permanent full-time role and soon working on new technologies and learning pods to support new curricula (Mujanovic 2017).

Future collaborative research and initiatives in the area of women in STEM strategy will ensure that prospective students from low socio-economic status backgrounds, who have the ability to study at university, get the opportunity to do so. Indeed, a successful transition from pre-tertiary to higher education and industry requires students to understand the nature of their chosen academic discipline and skills that can lead to successful career paths as well as engendering greater diversity within the STEM cohort (Christie et al. 2017). Given Western Sydney University's key strength in policy innovation, it is essential that we work together with the stakeholders to create, refine and evaluate existing and new policies affecting women and indigenous people in STEM strategies. Through the innovative delivery methods for STEM education above-mentioned, including industry-based learning, WSU can establish long-term and successful strategies within local communities to build,

attract and retain female and indigenous talents into STEM-based careers.

CONCLUSION

Overall summary: This white paper discussed the challenges (i.e. systemic & cultural barriers) that need to be addressed in Australia concerning women and indigenous people's underrepresentation and underutilisation within the STEM cohort. Since a STEM skilled workforce is essential to realising Australia's innovation and productivity potential, demand for STEM skills is high and will continue to grow until society tackles these challenges and make use of all the available talent. However, no single educational initiative, industry action or governmental policy can entirely solve the underrepresentation of women and indigenous people in STEM nor remove the barriers they face, unless a cohesive and collective action is taken to maximise the attraction, participation and retention at all levels. In fact, attracting women and girls of indigenous or non-indigenous culture to STEM and providing environments (i.e. learning & teaching) for them to thrive and progress is a mutual responsibility of government, academia, industry, the education sector, and the community. The strategies recommendations designed to facilitate systemic and sustained changes in achieving gender and cultural equity in STEM throughout the Australian workforce are as follows:

FIGURE 12: Opportunities and recommendations of the decadal plan (Australian Academy of

Science 2019)

Accordingly, the implementation of a national framework will demand bold, sustained and cohesive effort across the entire STEM ecosystem to deliver a healthy approach where girls and women from diverse cultural backgrounds are empowered through their STEM careers. In the 2018-19 Federal Budget, a Women in STEM Decadal Plan was announced that featured the above-mentioned recommendations (see Figure 12), with a shared vision for the future to attract, retain and progress women in STEM. Although limited performance data is currently available, we hope that this new integrated approach can serve as a key tool to monitor, improve participation and close the gender gaps in emerging STEM professions. Through the implementation of such a national framework, Western Sydney University can holistically identify the specific issues faced by Greater Western Sydney and develop translational region-directed solutions. Moreover, by recognising research-driven practice and policies around the world, the university could ensure that STEM educational pathways are culturally sensitive and are responsible to the needs of women from a range of backgrounds.

Our approach: The development of this White Paper has brought together researchers across disciplines, where future research and interventions will continue to build on this transdisciplinary approach, including engagement with key stakeholders and community leaders to form intersectional research teams that can comprehensively address STEM cohort issues in an integrated manner.

OUR AMBITIONS

This white paper has provided an overview of the strength and importance of the STEM cohort for underrepresented groups (i.e. women and indigenous people) in Australia. Despite a national framework being encouraged and progressively implemented at various levels, at Western Sydney University there is further work to be done in the short and long-terms that can considerably influence the opportunities and experiences for young indigenous women across Western Sydney region. Accordingly, the priority areas that could be pursued in future work include:

- Culturally supportive teaching and a community-based approach to curriculum design: By engaging with the local community, students, teachers and university faculty, a collaborative and integrated practice into indigenous STEM education and training is promoted towards STEM participation and literacy within the community.
- The use of social media for representing diversity across STEM fields: Indeed, social media is a powerful tool that particularly influences younger audiences, with 26% of people aged 18 – 29 identifying social media as their most trusted source of news compared to traditional sources such as radio, television and print media (Yellow 2018). Accordingly, engaging the Australian STEM ecosystem through social media could have a significant reach outside of the scientific community to inspire younger generations to pursue STEM careers. For example, at the university level, the organisation could support media and communication training, including social media presence, to encourage equity of representation of women (i.e. promoting role models) and challenge gender stereotypes in STEM.
- Future collaborative research between WSU researchers and relevant community stakeholders: This will ensure that our research continues to be revolutionary and published in peer-reviewed scientific publications, with findings presented at key forums and conferences to translate into best-practice policy and educational guidelines for the Australian population. Current research clarifies that we need to change the culture in STEM. As an institution in Western Sydney, we need to redefine what a scientist looks like in society. By increasing the number of female role models throughout the community, girls of various cultural backgrounds are more likely to be interested in STEM as it helps them envision themselves in these roles.
- Balanced and diverse decision-making committee: Institutions should ensure diversity in the selection process for organising a conference, reviewing candidates for an academic position or tenure, or evaluating grant applications, as studies suggest that having even one woman on speaker selection committees correlated with a significantly higher proportion of invited female participants. Therefore, by encouraging equity and diversity at university level, opportunities to reach and inspire new audiences, particularly young indigenous girls, is facilitated towards STEM pathways.

Looking into the future, WSU will continue to engage with our stakeholders in education and training, industry research, and policy innovation in the key areas of young indigenous girls and STEM, to promote participation and address the STEM workforce shortage. This will enable us to appreciate holistically, understand and formulate strategies to address the complex and diverse needs of STEM in Western Sydney.

AN INVITATION TO PARTNER

Western Sydney University is currently collaborating with WSP to create equitable, inclusive and sustainable societies for today and future generations. This is achieved through local engagement activities at school and community levels, connecting people, stimulating growth for Indigenous representation and STEM participation.

Accordingly, Western Sydney University is seeking similar partnerships to help develop and implement its intentions and commitments towards a culturally diverse and engaged STEM community.

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