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The Unconventional Strength towards STEM Cohort

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ABSTRACT

CONTEXT

Science, Technology, Engineering and Mathematics (STEM) play a critically important role in Australia's ability to innovate, expand and remain a competitive force globally. Ensuring that the workforce has the relevant skills in sufficient quantities is quite challenging and requires an understanding of how these skills are and will be used within the Australian economy. However, 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. female & Indigenous graduates) and diverse backgrounds. Currently, millions of children and young people are not developing the required skills to participate effectively in STEM environments, including STEM literacy valued for career progression in traditionally male-dominated fields (i.e. engineering & construction).

PURPOSE OR GOAL

This paper aims to highlight the significant challenges associated with STEM's gender and diversity, including the limitation of current approaches that can be translated and scaled to enhance the participation, engagement and representation of young indigenous and female students in Western Sydney and beyond.

APPROACH OR METHODOLOGY/METHODS

The challenges are drawn from recent literature, and a review of existing initiatives is presented based on the observations of key partners, including Western Sydney University, the Australian government, the 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, Australian workplaces and the government is essential, as no single sector can entirely solve the current STEM skills shortage.

ACTUAL OR ANTICIPATED OUTCOMES

This work has brought together researchers across disciplines, where future research and interventions will provide recommendations designed to facilitate systemic and sustained changes in achieving gender and cultural integration in STEM. The outcomes will emphasise the existing knowledge of current trends, issues, and strategies throughout the STEM cohort.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

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 of the economy. Moreover, by recognising research-driven practices and policies worldwide, educational institutions could ensure that STEM pathways are culturally sensitive and responsible for the needs of under-represented groups from various backgrounds.

KEYWORDS

STEM skills; Indigenous communities; Women in science; Transdisciplinary engagement

Introduction

The gender 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 paper mentions, the problem of gender and diversity equity in STEM cohorts 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 only 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.

While the current message delivered to students is the need to study STEM subjects, it is critical to provide context around STEM skills as a foundation for innovative thinking and real-world problem solving that will drive Australia's productivity and economic growth. 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 (Commonwealth of Australia, 2017). Therefore, this paper aims to highlight the significant challenges associated with STEM's gender and diversity, including the limitation of current approaches (i.e. educational and 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.

Key Literature Findings

Gender Diversity in Education

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 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 study. 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 and female students in STEM. Although some school are currently advocating for these STEM values, the urgent need is to scale up the initiatives to reach communities, especially within remote areas.

Moreover, with the future of work changing towards a digital environment, existing jobs are being modified and new ones are emerging at the frontiers of developing industries. These new opportunities require knowledge and skills in science, technology, engineering and maths (STEM), which workers are expected to possess within their employability competencies. Therefore, 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 qualifications are 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 policy makers — skills that quality STEM education can cultivate to transform society with innovation and sustainable solutions (Alam & Tapia, 2020).

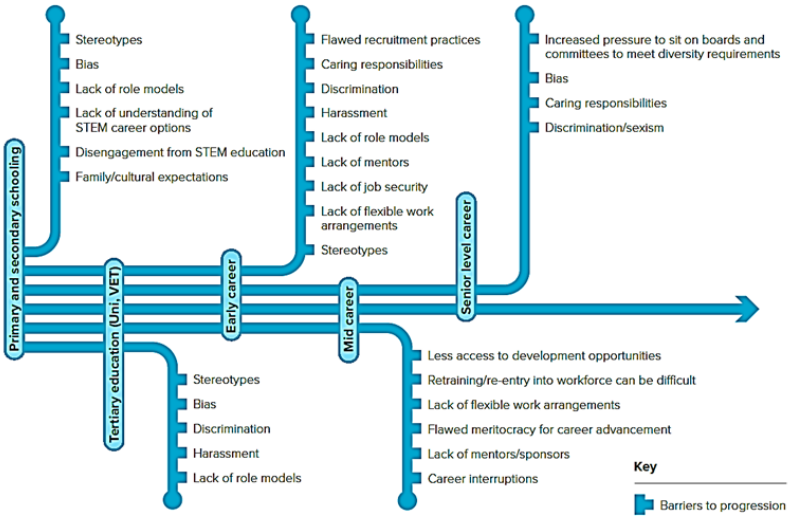

Figure 1: Career progression pipeline for women in STEM (Australian Academy of Science, 2019)

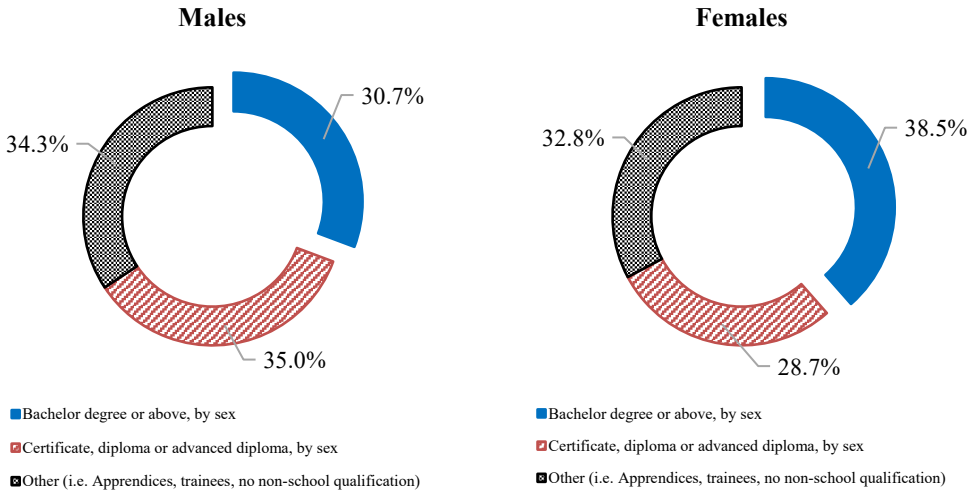

Figure 2: Qualifications attainment by level and gender for all persons aged 20-64 years (Australian Bureau of Statistics, 2020)

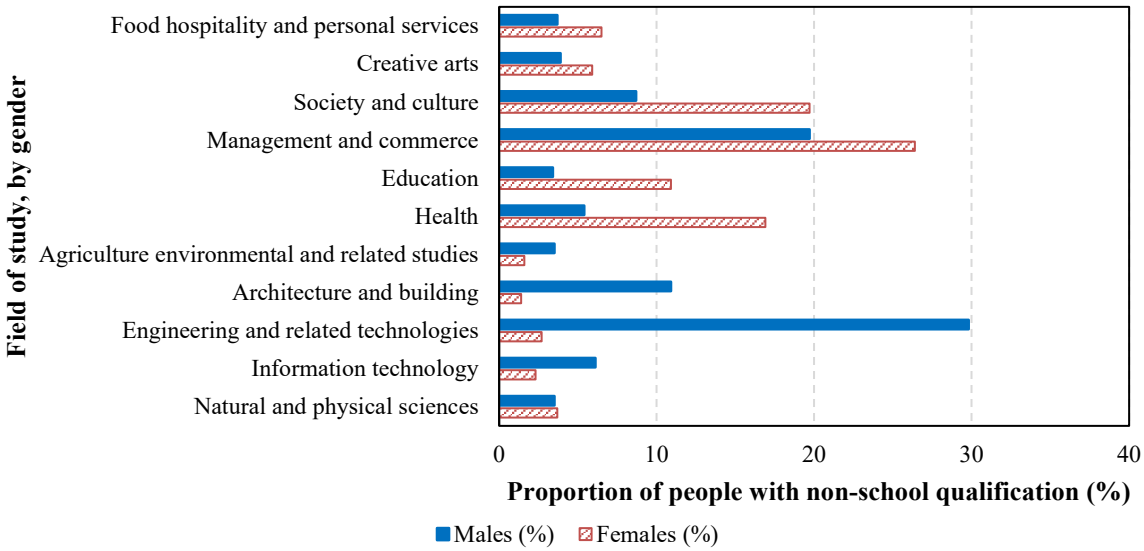

Figure 3: Field of study of highest non-school qualification, by gender (Australian Bureau of Statistics, 2020)

In Australia, 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 (by 17%, from 2004 to 2020), 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 2), the main field of study of their highest qualification was management and commerce (26%), followed by society and culture (20%). 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 3. Therefore, the underrepresentation of females in STEM is not simply because of an overall lower number of women with non-school qualifications; instead, women are less likely than men to pursue study in STEM related fields.

Although 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 allows 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 STEM and lack ot female role models are 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.

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, Gore, Smith, & Lloyd, 2018; Makarova, Aeschlimann, & Herzog, 2019). According to Alam and Tapia (2020), the key attitudes 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 begin at early age and compound over their lifetime.

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. 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.

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. 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:

Figure 4 illustrates the noticeable pay gap between men and women workers, 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 university qualifications earned an income in all brackets below $104,000. However, higher percentages of men (relative to women) with university qualifications earned an income in all brackets of $104,000+. 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. Such trend is not only a problem for STEM related work but is significant in careers where women and Indigenous people need to be enticed to participate in the field.

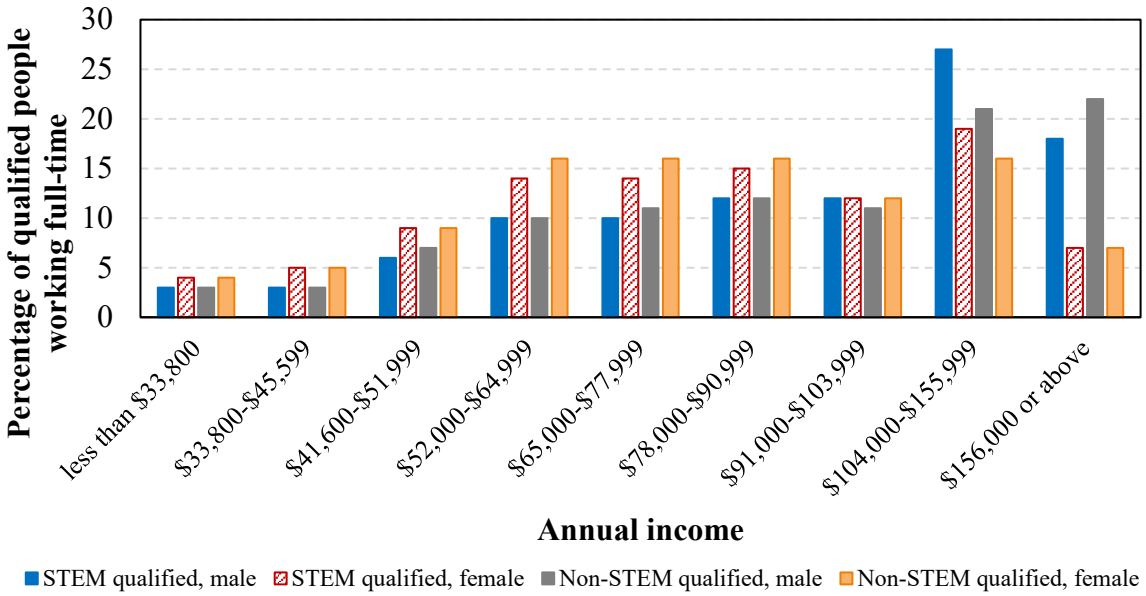

Figure 4: Income distribution of full-time workers with university qualifications, by field and gender

Lack of workplace flexibility (i.e. caring for children) and accessibility:

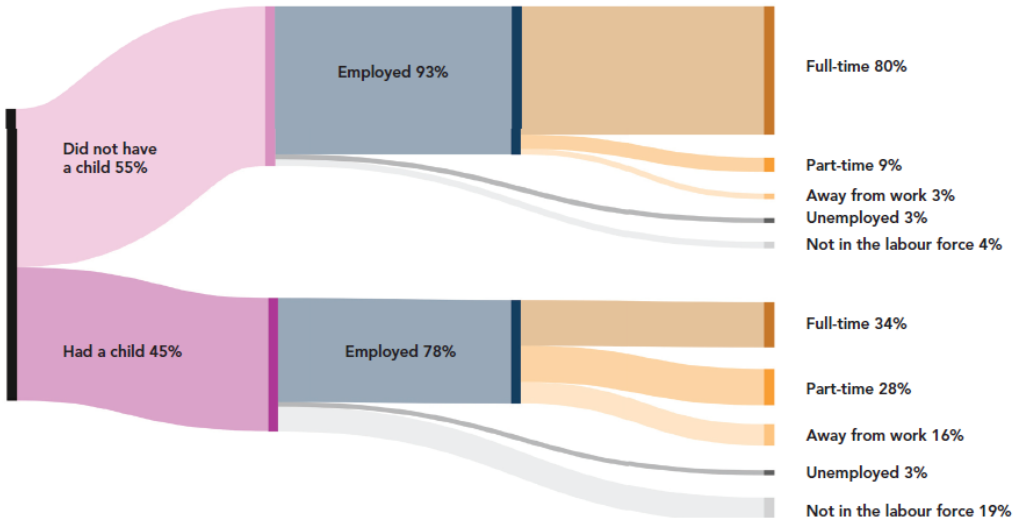

Figure 5: Employment pathways for females with STEM qualifications aged – university STEM

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 5) preferred to undertake part-time work or ultimately leave the labour force.

Bias, discrimination and flawed recruitment methods

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. For instance, while both men and women were severely affected by the pandemic (Covid-19), 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). Combined with an increased workload, 30% of women reported decreased productivity and 12% decreased income. In addition, 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.

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 background 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 are required to build the workforce for the future.

Current 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 and female students in Australia to pursue education and careers in STEM professions.

The Indigenous STEM Education Project 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 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). 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.

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 represents a ten-year $25 million endowment made by the New South Wales Government to attract, support, retain and train NSW students into STEM education and employment. 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 career pathways and opportunities;

While various governmental outreach programs and international practices that support minority groups (i.e. women and/or Indigenous groups) exist, this paper highlights the current Western Sydney University (WSU) commitments in promoting STEM values and careers. 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:

- 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.
- The School of Education's Master of Teaching STEM is an initiative to bring together pre-service teachers with schools in Sydney's west where STEM is well established in the curriculum.
- 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 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 students in STEM will connect them with industry partners through internships, mentoring and workplace training. This unique and global initiative also assists students throughout their degrees to reach their potential as the next generation of talented Indigenous engineers (Sardyga, 2020).

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, O'Neill, Rutter, Young, & Medland, 2017).

Conclusion

This study discussed the challenges (i.e. systemic & cultural barriers) that need to be addressed in Australia concerning women and Indigenous students' 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, mentoring 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. Therefore, this study's strategies and recommendations designed to facilitate systemic and sustained changes in achieving gender and cultural equity in STEM throughout the Australian workforce are as follows:

- The need for stronger cohesion and leadership across the Australian STEM ecosystem will amplify and strengthen diversity outcomes.
- Improving the visibility of the Australian STEM ecosystem through social media and public events could have a significant reach outside of the scientific community to inspire younger generations to pursue STEM careers.
- Facilitate equity and diversity at university level, opportunities to reach and inspire new audiences, particularly young indigenous girls towards STEM pathways.
- Engage with the local community, students, teachers and university faculty to promote a collaborative and integrated practice into indigenous STEM education and training towards STEM participation and literacy within the community.
- Initiate a cultural shift in workplaces to create gender equity for women in STEM. A culture that is inclusive and respectful, challenges traditional stereotypes, is free of discrimination and bias, enables flexibility and accommodates career interruptions and changes will maximise women's participation in the workforce.
- 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.
- Establishing a national framework that guides and provides tools to address gender equity amongst enterprises will impact the vast majority of businesses not reached by existing programs.

Accordingly, implementing these strategies and recommendations nationally 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 some of the recommendations mentioned above, with a shared vision for the future to attract, retain and progress women in STEM. Although limited performance data is currently available, we hope 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, institutions can holistically identify the specific issues faced by Greater Western Sydney and develop translational region-directed solutions. Moreover, by recognising research-driven practices 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.

References

Alam, A., & Tapia, I. S. (2020). *Mapping gender equality in STEM from school to work*. Retrieved from New York, USA: https://www.unicef.org/globalinsight/stories/mapping-gender-equality-stem-school-work

Australian Academy of Science. (2019). *Women in STEM Decadal Plan*. Retrieved from https://www.science.org.au/files/userfiles/support/reports-and-plans/2019/gender-diversity-stem/women-in-STEM-decadal-plan-final.pdf

Australian Bureau of Statistics. (2020). Education and Work, Australia. In *Survey data over time on current or recent study, educational attainment, and employment*.

Cheryan, S., Master, A., & Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: increasing girls' interest in computer science and engineering by diversifying stereotypes. *Frontiers in Psychology, 6*(49). doi:10.3389/fpsyg.2015.00049

Christie, M., O'Neill, M., Rutter, K., Young, G., & Medland, A. (2017). Understanding why women are under-represented in science, technology, engineering and mathematics (STEM) within higher education: A regional case study. *Production, 27*.

Commonwealth of Australia. (2017). *Towards 2025 An Australian Government strategy to boost women's workforce participation*. Retrieved from https://womensworkforceparticipation.pmc.gov.au/sites/default/files/towards-2025-strategy.pdf

Engineers Australia. (2018). Women in STEM Strategy. In.

Holmes, K., Gore, J., Smith, M., & Lloyd, A. (2018). An Integrated Analysis of School Students' Aspirations for STEM Careers: Which Student and School Factors Are Most Predictive? *International Journal of Science and Mathematics Education, 16*(4), 655-675. doi:10.1007/s10763-016-9793-z

Leigh, K., Hellsing, A., Smith, P., Josifovski, N., Johnston, E., & Leggett, P. (2020). *Australia's STEM Workforce*. Australian Government, Canberra

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The Gender Gap in STEM Fields: The Impact of the Gender Stereotype of Math and Science on Secondary Students' Career Aspirations. *Frontiers in Education, 4*(60). doi:10.3389/feduc.2019.00060

Sardyga, A. (2020). Western Sydney University launches program for aspiring Indigenous engineers. Retrieved from https://www.westernsydney.edu.au/newscentre/news_centre/more_news_stories/western_sydney_university_launches_program_for_aspiring_indigenous_engineers

Shapka, J. D., Domene, J. F., & Keating, D. P. (2006). Trajectories of career aspirations through adolescence and young adulthood: Early math achievement as a critical filter. *Educational Research and Evaluation, 12*(4), 347-358.

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

Walker, L., & Banks, C. (2021). *Indigenous STEM Education Project Final Evaluation Report: September 2014 – June 2021*. Retrieved from Canberra, Australia:

World Economic Forum. (2021). *Global Gender Gap Report* (ISBN-13: 978-2-940631-07-0). Retrieved from Switzerland: https://www3.weforum.org/docs/WEF_GGGR_2021.pdf

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