Australia's National Science Agency

Engaging Young Female Students in Digital Technology Programs

Part One: Findings Report for CSIRO

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1 Introduction

Promoting student engagement with STEM, including digital technologies, is crucial for the national interests of Australia for several reasons. Firstly, at the macro level, ensuring a digitally literate workforce is at the heart of the Australian government's tech future agenda, and considered vital for the economy (Australian Government Department of Industry, Science, Energy and Resources, 2018). Secondly, at the micro level, STEM skills are often highly valued in the workforce and individuals with these skills have more opportunities in the labour market. However, the recent national STEM Equity Monitor summary report (Australian Government Department of Industry, Science, Energy & Resources, 2020a) shows that females continue to be under-represented in STEM tertiary education programs and in the STEM workforce. Australia has a significant gender divide, with females accounting for only 39% of information media and telecommunications graduates (Australian Government Department of Industry, Science, Energy and Resources, 2018). This disparity widens when considering the workforce, with 2019 data showing only 14% of jobs requiring STEM qualifications were held by females (STEM Equity Monitor, 2020). Investigating ways to improve female engagement with digital technologies is therefore important for ensuring equity in the field and is a priority for the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

This report is part of a larger project commissioned by CSIRO and designed to highlight the enablers and barriers to young female students engaging with digital technology. By addressing this function, the report will thereby aid CSIRO to increase the participation of young female students in the digital technology programs offered by CSIRO's Education and Outreach (CEdO) unit. CSIRO's Digital Careers team have developed activities and resources to enhance and extend students' computational thinking skills and to develop other integral skills such as teamwork, critical and creative thinking, and problem solving. In collaboration with industry partners, CEdO are responsible for running programs for primary and/or secondary students, including CyberTaipan, Microsoft FarmBeats and Bebras. The overall goal of Digital Careers is to support both teachers and students by developing resources aligned with the Australian Curriculum, and design challenges and learning experiences to enrich students' understanding of digital technologies and prepare them for the ever-changing requirements of the workforce.

This report has five parts. First, the results of a brief literature review are discussed with a focus on understanding the key enablers and barriers to young female students' engaging with STEM and digital technology. Second, relevant policy aimed at increasing engagement in digital technology and STEM are considered. Third, a review of alternative digital education programs that are designed to engage female students in digital technology and/or STEM is given. Fourth, a brief review of CSIRO's internal programs, CyperTaipan, FarmBeats and Bebras, is presented that compares the design of the programs with key findings in the research literature in the research literature and the Australian, the Australian Curriculum. The review also considers the extent to which the materials reflect any diverse contexts for different parts of Australia, such as recognition of the experiences of First Nation peoples in Australia. Fifth, recommendations are outlined for ways to increase young female students' participation in the CEdO programs based on the findings from the literature, policy and program review.

Please note that in this report, the term 'female' includes those who are cisgender, transgender, non-binary, and intersex persons who identify as female.

2 Literature Review

Australian data shows that young female students outperform their male peers in digital literacy tasks in assessments delivered at grades 6, 8 and 10 (DeBortoli et al., 2014; Fraillon et al., 2018). However, a wealth of research also demonstrates that female students report less engagement with digital technology (Australian Department of Industry, Science, Energy & Resources, 2020a; OECD, 2018b; West et al., 2019). For instance, findings from the 2019–20 Youth in STEM Research survey (Australian Department of Industry, Science, Energy & Resources, 2020b) indicate 27% of school-age females (12 to 17 years old) aspired to have a STEM-related career in the future, compared to 42% of school-age males (Australian Government Department of Industry, Science, Energy & Resources, 2020a). The ICILS 2013 assessment showed that, while Australian Year 8 female students scored significantly higher than Australian male students on a set of computer and information literacy tasks, male students were significantly more confident in their capacity to accomplish advanced ICT tasks than female students (De Bortoli et al., 2014). Studies suggest that female students' lack of engagement and choice to steer away from careers involving digital technology likely stems from the gender differences previously discussed in students' attitudes and confidence beliefs (OECD, 2015, 2018b; De Bortoli et al., 2014). Consensus in the literature points to barriers such as unequal access to education, as well as socio-cultural norms and parental biases as being the fuel for the gender-based digital exclusion (OECD, 2015; 2018 a, b, c; Hilbert, 2011; Cooper, 2006; Korupp & Szydlik, 2005; West et al., 2019).

Research also suggests that gender differences in engagement are more likely to emerge during early adolescence and be less prevalent in the primary school years. For instance, a study conducted in the United Kingdom (UK), found that female and male students' interest in science, technology, mathematics, and engineering (STEM) subjects was nearly equal at ages 10 and 11, with only a three per cent gap in favour of males; however, by age 18, the interest gap increased to 14 per cent (Kearney, 2016; West et al., 2019). In a longitudinal analysis, McMillan et al., (2021) found that the level of mathematics value students reported at age 15 – specifically valuing mathematics because it is useful for the future – significantly predicted students' choice to pursue tertiary STEM studies. This effect held even when mathematics achievement and other background characteristics were taken into account. For female 15- year-old students, the level of confidence they had in their mathematics capabilities also significantly predicted their participation in STEM tertiary studies. Watt et al., (2019) found that Year 10 students who were classified as disengaged with mathematics and science – i.e., those who did not like these subjects, perceived the effort and social and psychological costs of pursuing these subjects as high but could appreciate the value of mathematics and science study and skills – were less likely to be interested in pursuing STEM careers. They also found that there was a greater proportion of young females' that fit these disengaged criteria in mathematics than their male peers.

This research suggests that (1) understanding the factors that lead female students to engage or disengage from the STEM pathway in early adolescence may be crucial to improving female students' participation in digital technology programs, and (2) identifying environments, conditions and initiatives that raise female students' interest, value and confidence in STEM and digital technology specifically may be key to understanding the enablers and barriers to engagement with digital technology. The following section of the literature review summarises key research findings on the:

- Factors that shape interest, value and confidence (influencing factors)
- Factors that hinder young female students from engaging with digital technology (barriers)
- Factors that facilitate young female students from engaging with digital technology (enablers)

Table 1 Factors which influence young female students' engagement in digital technologies programs

INFLUENCING FACTORS	ENABLERS	BARRIERS
Early exposure and access: Research indicates that students' career aspirations are largely formed by age 13 and after this point are progressively harder to change (West et al., 2019) thus implying that early intervention and exposure to digital technology is a key to engaging more female students in digital technology programs.	Research suggests that female students acquire gendered notions of intelligence and aptitude as early as six years of age, and these beliefs extend into adulthood (Bian et al., 2017; West et al., 2019). As a result, introducing digital skills to female students at the pre-primary level is expected to be highly beneficial. Additionally, extracurricular and outreach activities have been found to foster an early interest in STEM related subjects and stop the formation of stereotyped and gender-biased views of scientists (Siani, & Dacin, 2018). A study in the US found that female students who had exposure to computing in junior high school were 18% more likely to report interest in pursuing computing studies in later high school and in tertiary education (Accenture, 2016). The Computational Thinking Educational Policy Initiatives (CTEPI) study found that ensuring computational thinking is integrated into compulsory subjects or made a compulsory subject, results in greater access to computational science concepts for all demographic groups (Hsu et al., 2019).	Cyber-safety has been reported by families as a key reason for limiting the use of the Internet for female students and denying them access to mobile phones (OECD, 2018b, c). The UNDP (2021) reports that concerns regarding data safety and threat of online harassment are a key barrier to female students' access to digital services, particularly for those from First Nation and minority backgrounds
Socio-cultural norms: Gender stereotypes and cultural biases from both within and outside the family may deter young female students, particularly during early adolescence, from starting/continuing to engage in digital technology programs (West, et al., 2019).	Research suggests that female students who think computing is "cool" can have around 11% greater interest in pursuing digital technology programs, while those who think computing is "for girls" will have at least 25% higher interest than those who don't (Accenture, 2016).	Social stigma against females playing video games or computing being a "boys only" activity may prevent parents and teachers from seeing them as educationally beneficial to female students (Accenture, 2016; Gil-Juárez et al., 2018, West et al., 2019). Also, media representations of males as computer scientists and engineers in family films is reported to "outnumber portrayals of females by 14.25 to 1" (Accenture, 2016, p.10).
Parental engagement, expectations, and support:	Parental support has been strongly associated with their children's' computer	ICT socialization in the family is likely to hinder gender-equitable access to

Research shows that parents can either reinforce or help dismantle harmful gender stereotypes about intelligence, aptitude, and 'appropriate' fields of study for females (Sey & Hafkin, 2019; OECD, 2018b).	self-efficacy (Vekiri & Chronaki, 2008; Vekiri, 2010), while gender differences in computer attitudes have been linked to gender differences in students' perceived encouragement from their parents (Meelissen & Drent, 2008). Additionally, Schorr (2019) emphasizes the important role that fathers (and teachers) play and that their encouragement and support can improve female students' participation in digital technology programs (Vekiri, 2010). Female students' self-efficacy and attitudes related to STEM are strongly influenced by their immediate family environment, especially their parents. Female students from higher socio- economic backgrounds with parents who have higher educational qualifications, are likely to hold more positive attitudes towards STEM than females from lower socio-economic status, of immigrant status and ethnic minority background or single parents (UNESCO, 2017). Research also indicates that a culturally responsive family engagement strategy can maximize the strengths, interests, and needs of minority communities, as in the case of the Somali immigrant female students in the USA where the *Techbridge Girls program* used a peer-to-peer social connection among parents to run parent workshops in collaboration with the local Somali Youth and Family Club (SYFC) community group leaders (Sammet & Kekelis, 2018).	ICT education and access to ICT careers for females (Schorr, 2019). Galdi and colleagues (2017) found that children as young as six were influenced by their fathers' (but not their mothers') stereotypical beliefs and this predicted their own endorsement of gender stereotypes in mathematics and language. In many contexts, parents have been found to treat daughters and sons differently in terms of ICT access and use, often introducing technology to the female child later than the male child, imposing more restrictions on its use and prioritising males' access over females' (West, et al., 2019). Data from Spain shows that while fathers regularly played video games with their sons this was not the case for their daughters (Gil- Juárez et al., 2018). The same study shows that mothers never played video games with any of their children, emphasising the stigma that some digital activities such as video games, are only for males (Gil- Juárez, et al., 2018). Additionally, in a recent study conducted in Germany, fewer female students reported being mentored by their father in terms of computer and Internet usage than their male peers (Schorr, 2019).
Teacher skills, attitudes, and beliefs: Research has found that teachers' perceptions of sex-based ability can have a negative impact on female students' pursuit of technology- related studies (UNESCO, 2017).	Female teachers' self-efficacy, or confidence in their knowledge of ICT, their digital skills and their ability to teach it, has been linked to their female students' achievement in STEM subjects (UNESCO, 2017). This relationship was not found for female teachers and their male students.	Results from the Third Regional Comparative and Explanatory Study (TERCE) 2013 study from Latin America, found that 8% - 20% of mathematics teachers in Grade 6 believed that mathematics is an easier subject for their male students, and this had an influence on their classroom interactions with male versus female students (Sayman, 2013). Evidence from Asia also show that 65% of all student-teacher interactions in mathematics classes were with male students, while in science classrooms 61% were with male students (UNESCO, 2017).
Role models: "*Mothers, more than fathers, appear to have a greater influence on their daughters' education and career choices, possibly due to their role- model function… Media representations of women, and the status of gender equality in society also has an important influence, as it influences the expectations and status of*	Research indicates that recruiting and training more female ICT teachers is beneficial for female students and positively influences their interests in ICT (Unterhalter et al., 2014; West et al., 2019, Accenture, 2016). Female teachers can positively influence female students' perceptions, interest and confidence in STEM subjects (Rabenberg, 2013) as well as their STEM career aspirations (Stearns et al., 2016; Kearney, 2015; Carrell et al., 2009).	Research has also found that high-school students may perceive their teachers to have stereotyped views about the appropriateness of ICT for males and females (Shashaani,1993).

women, including in STEM careers." (UNESCO, 2017, p. 12).		
Pedagogical strategies and tools: Learning tools, assessment content and pedagogical strategies can affect female students' learning outcomes in technology subjects (UNESCO, 2017).	Research shows that female students tend to perform better in a supportive and bias free learning environment that uses teaching strategies which consider their differentiated learning needs (UNESCO, 2017). There is also evidence that visually appealing content that incorporates real-life, relevant contexts is more likely to engage young females in ICT tasks (Hubwieser et al, 2016). Hands-on activities, such as time spent in laboratories, extra-curricular activities, field trips, camps, mentoring arrangements, and apprenticeships, can help inspire and influence female students' interest, motivation, and confidence (UNESCO, 2017). A study from Israel found that females in secondary school were likely to spend more time with digital learning materials on a mobile device in a group-learning (collaborative) setting than using the device individually (Reychav et al., 2017).	Curricula that does not reflect female interests and is not gender-balanced (e.g. where content reinforces or does not work to challenge gender stereotypes), could hinder female students' interest and engagement in technology related subjects (UNESCO, 2017). Portrayal of females in STEM related roles in school textbooks is under- represented, which can subliminally influence female students' beliefs and engagement (UNESCO, 2017).
Cybersafety and online behaviours: Cybersafety guidelines and policies should reflect the typical online behaviours of females from various age groups and from different sociocultural contexts to ensure there are clearer directives about their online safety and wellbeing (Thompson, 2016).	Adolescent females' everyday interaction with peers and close friends has implications for their online safety and wellbeing. Female students tend to be more socially focused and are likely to face higher peer pressures than their male peers (Common Sense Media, 2012 and Cortesi, et al., 2015). Thompson (2016) notes that more information is needed on how female students manage their online experiences with peers and that this information should be used to inform cybersafety policies, guidelines, and recommendations (including those that are gender-specific) as this is key to protecting online wellbeing (Thompson, 2016).	Research suggests that young females are at higher risks of online harassment, psychological exploitation, or cyber abuse (Thompson, 2016). The risks are also higher for students from minority backgrounds, such as First Nations students (Carlson & Frazer, 2018; Mobin, Feng & Neudorf, 2017; Broll, Dunlop & Crooks, 2018). The online safety issue may be especially important for females aged 12 to 14 years; evidence suggests that the online challenges faced by female students at this age are very different to those of their male peers (Commonwealth of Australia, 2011; Cross et al., 2009; Lenhart et al., 2011; Livingstone et al., 2011).

NOTE: ICT = information and communication technologies

In addition to the research summarised in Table 1, there is also evidence that adolescent females from disadvantaged backgrounds face challenges in terms of access to ICT services for the purpose of interacting with information, knowledge, and people outside their local area (Cummings & O'Neil, 2015). Some researchers contend that improving exposure and engagement with ICT for female students, particularly those from disadvantaged and minority backgrounds, will not only help to improve their self-confidence but also empower them to consider the traditional gender roles that are endorsed within their communities (Cummings, & O'Neil, 2015). In Australia, only about 63% of First Nations peoples have access to the Internet at home compared with 91% of other Australians (ABS, 2011; Walker et al., 2021). Canadian research suggests that First Nations peoples may experience higher rates of cyberbullying than non-First Nation Canadians (Mobin, Feng & Neudorf, 2017; Broll, Dunlop & Crooks, 2018); however, there is a lack of research investigating the type and impact of cyberbullying experienced by First Nation peoples in Australia. Studies demonstrate that the way that First Nation peoples engage with mobile devices and social media can be culturally driven illustrating the need for research that focuses on how this specific use may translate to different types of cyberbullying experiences, and require specific cybersafety guidelines and policies (Carlson & Frazer, 2018).

3 Policy Review

In this second part of the report, relevant policy aimed at increasing engagement in digital technology and STEM are considered.

According to a report by the European Union (Boconni et al., 2022), at least 25 countries have recently introduced policy that dictated digital technology related components – such as computational thinking skills – are a compulsory part of the curricula in education at the primary and lower secondary school levels. Other policy-related decisions include investment in building infrastructure and upskilling teachers to support these policies. Examples of these policies are provided in the next section.

3.1 Integrating digital technologies related subjects into compulsory curricula

Many countries, including Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Hungary, Ireland, Israel, Japan, Lithuania, Malta, Poland, Portugal, Slovakia, South Korea, Spain and the United Kingdom have revised their compulsory curricula in recent years to include a computer science subject (Boconni et al., 2022). For example, in the UK, computer science classes are mandatory for students aged five to 16, and in Finland integrated ICT skills are now included across the curriculum at all levels. In the Republic of South Korea, compulsory software courses are taught from primary through secondary school and in Japan, since 2020, computer programming has become a compulsory subject in primary school.

Across these examples, it is evident that the way in which computer science is implemented into compulsory curricula varies across education systems with three methods typically used:

(1) computer science concepts are considered cross-curricular and taught across subjects, (2) computer science concepts are taught as part of a dedicated computing subject, and (3) computer science concepts are taught within specific subject areas (e.g. mathematics) (Bocconi et al., 2022).

3.2 Adopting inclusive "digital" policies

Some education systems such as Québec (Canada) are adopting approaches to consider the cultural and sociological characteristics of diverse populations and collect recommendations from First Nations students around their digital needs (Ministry of Education and Higher Education of Québec, 2018).

3.3 Increased spending on ICT

Many governments around the world are increasingly spending more funds to encourage digital technology use in schools to ensure students get access and exposure from an earlier age. For example, in Germany in 2019 the federal government invested five billion euros under the DigitalPakt Schule (with the state governments each contributing a minimum of ten percent of the amount invested by the federal government) to ensure that schools are better equipped with digital technology (European Commission, n.d.).

3.4 Support for teacher training and professional development

Sweden's National Education Agency provides professional learning courses on programming online for secondary school mathematics and technology teachers and these courses are also offered to teachers of other subject areas. Teachers that participate in these courses can count this towards their annual quota of professional learning (Boconni et al., 2022).

3.5 Transforming assessments

Both Sweden and Australia have decided to implement their national assessments online. Federal, state and territory education ministers have agreed that all schools should be performing the (Australian) NAPLAN test online by 2022 (Eurydice, n.d.; ACARA, 2022c).

Besides digitising national assessments, other organisations are designing assessments to investigate students' computational thinking skills. According to the OECD's website, PISA 2025 Learning in the Digital World assessment will specifically focus on two competencies that are essential to learning with digital technologies – self-regulated learning and computational and scientific inquiry practices (OECD, n.d.).

4 Alternative Program Review

4.1 Selecting the alternative digital education programs

In this third section of the report, a review of alternative digital education programs is presented. The review targeted alternative programs that focused on engaging young female students and also sought out those that aimed to expose female students to digital technologies in pre-primary to primary age and/or females from lower socio-economic areas, remote and rural areas, or students with First Nations and/or immigrant backgrounds. Additionally, we investigated programs that involved the following elements and/or aims:

- addressing stereotypes about females in digital technologies and/or engaging female role models
- increasing young female students' engagement and sense of value of digital
- technology
- engaging females through marketing, partnership and advertising initiatives
- engaging parents
- providing resources for supporting teachers.

We analysed 20 programs and a selection are highlighted in Table 2.

Table 2 Alternative selected digital education programs

PROGRAM	AGE	DELIVERY	UPTAKE	GENERAL INFORMATION	FEATURES
She Maps (https://shemaps .com/)	4 -18	During school times as well as online outside of school	Open to everyone	An Australian program that can be accessed worldwide. The program provides hands-on experience with flying drones, coding for automated flights and teaches students how to use geospatial mapping principles.	She Maps hosts professional learning for teachers. One of its main foci is to increase teachers' confidence in teaching STEM. So far, over 1500 teachers have participated in 12 countries across the world. She Maps also features females in many of the drone scenarios.
Girls Who Code (https://girls whocode.co m/)	8 -25	After school clubs, summer camps (online and face-to-face) and an alumni community with events for college- aged and early career students	Females and non-binary students only. Fifty percent of participants are from historically under-represented groups (e.g., low-income backgrounds, Latinx, African American) (Girls	A US program that can be accessed in other countries. School-age participants learn coding and make an impact in their community while preparing for a career in digital technologies. For college-aged students, there are hiring summits and alumni communities so students can access mentoring, meet potential	Girls Who Code surveyed participants to provide better support tuned to their needs. They also run an alumni community and mentorship programme. They run multimedia marketing campaigns like "Make That Change" featuring diverse role models. They also partnered with Doja Cat (https://dojacode.com/) to

			Who Code, Annual Report 2021).	employers and support each other. Girls Who Code prioritises flexibility and accessibility through more virtual options, and a drive to reach as many females as possible.	make a codable music video.
AspireIT (https://www.aspirations.org/get- involved/aspireit-near- peer-computing-programs)	4-18	AspireIT Impact Award funds community programs such as after-school events, camps and hackathons.	Females and non-binary students only. According to the AspireIT website, 75 percent of participating students reported they would consider taking future Digital technologies courses after participating in the program.	A US program but can be accessed in other countries. AspireIT programs must connect communities, create opportunities for marginalized populations and grow interest in computing. For example, the Colour of Our Future program is especially designed for females of colour (Latinx, Native American and African American). All programs contain near-peer mentorship; that is, mentors should be near, but slightly further along, in their learning than the mentees, as discussed on the NCWIT AspireIT Toolkit website.	AspireIT uses a toolkit based on NCWIT Engagement Practices Framework. This toolkit for teachers and facilitators has a strong focus on mentorship, inclusivity, and hands- on engagement.
Digital Youth Divas (http://digitalyouthnetwork.org/divas/)	9-13	Out of school	Females, especially from low socio-economic communities and communities under-represented in computer science and engineering (e.g. First Nation communities).	A US program that teaches computational and digital literacies through modules and the creation of digital artifacts such as e- fashion. The modules contain narrative stories which challenge race and gender stereotypes, and common stereotypes in computing, according to the Digital Youth Divas website.	Digital Youth Divas has Caring Adult Network Workshops especially for parents and caregivers. Mentors guide students and act as role models as students work both collaboratively and independently via online and face to face modes.
Indigicade (http://www.indigenousroutes.ca/)	13-24	Workshops in 2015 and 2016	First Nation females	A Canadian program that provided participants with training and mentorship to make their own video games.	Participants learnt from experienced artists, musicians, game designers and programmers.

4.2 Key Aspects Discussion

The 5 selected programs all have unique features that help engage young female students in digital technology. Both She Maps and AspireIT support programs and resources for pre- school females and children. Pippa and Dronie: A Children's book is produced by She Maps and is written by educators for children from Kindergarten to age nine. The book focuses on diversity in STEM, providing readers with real-life female role models that travel Australia and go on adventures with drones. The book features six female scientists and drone professionals and is associated with the 'Drone' block coding game, which can be downloaded from Apple or Google Play. For every book purchased, a book is donated to Ardoch or Deadly Science. For further information, please see the She Maps website.

The introduction of female role models is a large focus for other programs such as Girls Who Code, AspireIT and Digital Youth Divas. In 2021, Girls Who Code ran a multimedia campaign during International Day of the Girl called "Make That Change" (Girls Who Code, Annual Report 2021). The video features a diverse group of female digital technology role models and conveyed the message: "when you learn to code, you can not only make the change you want to see in the world, but by choosing a career in tech, you can change your life too". As part of their six-month virtual mentorship program, US college students were able to connect with role models in industry for monthly mentoring. Girls Who Code's alumni community is designed to encourage young female students to continue in their digital technology interests and passions, from school to college, to the workforce. According to the 2021 Annual Report, alumni from Girls Who Code are seven times more likely than the US national average to earn a computer science degree.

AspireIT takes a different approach to mentorship than She Maps and Girls Who Code. They are strong supporters of a peer mentorship model as they claim that students from kindergarten to secondary school are more likely to benefit from mentors that are slightly older (e.g. advanced by a few learning stages) as these mentors help students feel less threatened by the content, help build personal connections and inspire students to follow their interests in digital technologies.

Another method for engaging students with digital technologies is through parental involvement. Digital Youth Divas runs Caring Adult Network Workshops which are specially designed for parents and caregivers. These workshops connect families and communities to the learning activities and enables facilitators to engage with communities and their cultures and interweave those cultures, histories, expertise and networks into digital technology activities according to the Digital Youth Divas website. The workshops are run in person, and materials are provided online for caregivers who cannot attend the in-person session. They cover the background of the program as well as helping parents to be learning partners, and helping parents to identify and capitalise on learning opportunities. According to the Digital Youth Divas website, participants and parents have provided positive reports of working together to create digital technologies artifacts such as LED flowers and e-cuffs. The program builds on research that has found that parental involvement in the creation of digital products or artefacts is more important for a child's engagement in producing digital artifacts than peer influence for children in the early years, and peer influence becomes more significant after age 10 (Barron et al., 2009). In a research evaluation of the Digital Youth Divas program, it was found that the program increases knowledge for female students with and without prior learning experiences in digital technology, and successfully engaged females in computational practices in ways that transformed their thinking about digital technology and about themselves and their participation in this domain (Pinkard et al., 2020).

Like Digital Youth Divas, Indigicade is a program especially designed for female students from communities under-represented in computer science. According to the Indigenous Routes website, the Indigicade program had a small group of First Nation female students working with experienced artists, musicians, game designers and programmers to create their own games.

Engaging under-represented communities was also a major focus of Girls Who Code, with over 50% of the female students participating being from historically under-represented communities such as low-income, Latinx, Hispanic and African American (Girls Who Code, Annual Report 2021). The *Girls Who Code* team surveyed participants on barriers to participation and found that these included access to reliable wifi, laptops, and quiet places to work. The program has run campaigns in newspapers such as the New York Times, as well as the previously mentioned multimedia campaigns. One of their largest campaigns was a partnership with Doja Cat where they developed the world's first codable music video, for the song "Woman". Users could unlock hidden video content using CSS, Javascript and Python and did not need prior coding experience to participate. By enabling users to edit the video and change various details (e.g. nail designs and sky colour) the campaign was aimed at reaching a new audience of young people to illustrate the creativity and possibilities involved in coding. Users could then download or share their videos through social media.

Another method employed in the selected programs for engaging young female students is through training teachers in digital technology pedagogies. *She Maps* and *AspireIT* provide extensive professional learning resources and toolkits for teachers. *AspireIT* provides teachers with access to evidence-based resources such as how to use structured collaborative learning, how to encourage student interaction, and using meaningful and relevant content. These resources can be accessed for free through the Engagement Practices Framework (https://ncwit.org/engagement-practices-framework/) on the AspireIT website. She Maps provides teachers with a professional learning community, and resources which can be purchased such as lesson plans and materials aligned with the Australian curriculum. These resources are designed in conjunction with industry partners and come with extension activities, as advertised on the She Maps website.

In summary, the selected programs had the following key features:

1. Stories and apps for pre-school children showing female role models in relevant, local contexts
2. Multimedia campaigns showing a diverse range of female role models in digital technologies
3. Virtual mentorship programs for college-aged students connecting them to mentors in industry
4. Alumni communities and peer mentoring opportunities
5. Engagement of parents with their middle school children working collaboratively on digital products or artefacts
6. Partnering with musicians and gaming companies to engage people with little prior coding experience
7. Providing resources for teachers to enhance their pedagogy in digital technologies teaching.

5 CSIRO Program Review

This section of the report is dedicated to reviewing the internal digital education programs managed by CSIRO’s Digital Careers team. In collaboration with industry partners, CEdO run a variety of programs for primary and secondary students, including Bebras, CyberTaipan and Microsoft FarmBeats.

Bebras, an international program, is designed to cultivate Informatics and Computational Thinking skills among students. It is structured as a challenge to help engage students in computing and the application of information technologies. Bebras provides participants with a set of tasks that require comparing and solving real, cross-disciplinary problems where the solution path is not immediately obvious. Students can participate individually or in teams of up to four and the challenge is broken up into five age groups: Grade 3 and 4, Grade 5 and 6, Year 7 and 8, Year 9 and 10 and Year 11 and 12.

CyberTaipan is an Australian cyber defence program for secondary school students based on the CyberPatriot program, which is developed in the US. Both CyberTaipan and CyberPatriot are designed to engage students with cyber security and promote interest in related STEM subjects. CyberTaipan consists of a national competition and week-long holiday camps, however due to the COVID-19 pandemic, these ‘Cyber Camps’ have not been implemented recently as part of the program. Students compete in teams through several rounds of competition to address cyber security problems.

Microsoft FarmBeats for Students is an interactive program designed to empower students in Years 9 and 10 to develop and apply their digital skills and knowledge to agricultural challenges by investigating big data, artificial intelligence and machine learning. The program was implemented as a pilot in 2021, with expansion of reach and resources, including teacher professional learning sessions, resources and activities, teacher’s involvement in program material development and student engagement in inquiry projects, anticipated in 2022.

5.1 Alignment to the Australian Curriculum

Many strategies for improving female participation in computing and digital technologies are not different in principle to approaches used in other disciplines (e.g science and mathematics) that have aimed to address the under-representation of female students. While interventions in other STEM areas have demonstrated some success, improving female students’ participation in computing and digital technologies remains a challenge (Zagami et al., 2015). It has been suggested that the compulsory curriculum for mathematics and science education has provided a supporting foundation for interventions designed to improve female student participation and engagement as well as a space to foster the benefits of these interventions (Zagami et al, 2015). A compulsory curriculum for digital technology has only recently been introduced in Australia. The development of the Australia Curriculum: Technologies (AC:T) began in 2012, and since 2016 has been a compulsory component of student’s F-10 education, with notional time allocations recommended by ACARA (ACARA, 2012). In a similar way to other disciplines that have required interventions to improve female student participation, the Australian Curriculum: Technologies can provide the framework for supporting approaches to improving the participation of female students in digital technologies.

In addition to the AC:T, the Australian Curriculum provides further opportunities to support student learning in technologies through the general capabilities of Information and Communication Technology, Personal and Social Capability, and Ethical Understanding (ACARA, 2022b). The Key Learning Areas of Health and Physical Education, Digital Technologies and English also outline the importance of explicit content relating to technologies, including aspects such as online safety that have been developed in consultation with the e-safety Commissioner.

Bebras Australia develops and provides resources to prepare and support participants for the Bebras challenge that can also be used in teaching and learning contexts. Bebras 365 provides access to previous Bebras Australia challenges with solutions guides that align each task to the key concepts that underpin the AC: Digital Technologies (AC:DT) and the six identified computational thinking skills. Bebras Unplugged provides printable cards that are suggested for use as classroom activities and extension ideas. The Bebras Australia Solutions Guides provide alignment to the key concepts of the AC:DT required to complete each task. The key concepts that underpin the AC:DT establish a way of thinking about problems, opportunities and information systems and provide a framework for knowledge and practice (ACARA, 2022a). Classroom activities and worksheets, ICT Innovators activities and Computational Thinking in Action resources that are available on CSIRO's Digital Careers website provide teaching and learning resources explicitly mapped to the content descriptions of the AC:DT, ICT general capability and Critical and Creative Thinking continuum to support the development of student's capabilities in Digital Technologies.

CyberTaipan provides a suite of modules and resources to support students and teachers in preparation for the CyberTaipan competition. The modules include presentations and workbooks for students, and while much of the content aligns with aspects of the AC, explicit connections are not provided. The resources direct teachers to the University of Adelaide MOOCs on Teaching CyberSecurity and Awareness. The courses are designed to unpack the key concepts of the Australian Curriculum: Digital Technologies and the ICT general capability and present practical classroom activities for teachers to use to implement these teaching areas.

The Microsoft FarmBeats for Students pilot program was designed to align with the Australian Curiculum: Technologies. As part of the pilot program, teachers were provided with a set of classroom resources and guidelines to implement an inquiry-based assessment activity. CSIRO is currently exploring options for future iterations of the program, including strengthening links with the Australian Curriculum.

5.2 Elements to engage young female students – role models and mentors

The literature review contained within this report emphasised the importance of female role models for improving the engagement of female students in STEM learning. Furthermore, selected alternative digital education programs, such as Girls Who Code and She Maps, included female role models and mentoring to facilitate the engagement of young female students. All CEdO programs provide an element of mentorship to support successful engagement with the programs. Bebras requires a teacher, parent/carer or tutor to register as a coordinator who can then support students in preparing and participating in the Bebras challenge. The Bebras Impact Pathway document also indicates that pre-challenge and Computational Thinking webinars are a key deliverable in supporting the Bebras program.

CyberTaipan provides teams with technical mentors for additional support and technical expertise to participants. Mentors are guided by the team coach to ensure the support is tailored to the needs of the team and can include sharing career advice or experiences, teaching cyber defence skills and cyber ethics and providing training events. CyberTaipan also incorporates a Cyber Security Expert Q and A session to introduce additional real world cyber security specialists and increase coaches', mentors' and students' knowledge. In 2020, two of the three panellists in the CyberTaipan Expert Q and A session were females with expertise in the cyber safety industry. The CyberTaipan award presentation in 2020 was delivered by the female head of the Australian Cyber Security Centre.

Involvement in the Microsoft FarmBeats is facilitated by a teacher and aims to build a Community of Practice that will provide students with the opportunity to engage with experts through sharing their project outcomes with their peers, communities and industry. The type and frequency of mentor's engagement with students in CEdO programs varies, although the incorporation of these aspects in the programs is of critical importance. The value of mentorship and role models for female students in digital technology programs is reflected in a case study report of the US CyberPatriot program, with one female participant emphasising the positive impact of peers through their support as encouraging teammates and peer teachers (Brough, 2016).

Peer-collaboration is an important aspect of all CEdO programs as students have the opportunity to work in teams. For Bebras, students can choose to work alone or in groups of up to four students. An evaluation of gender differences of students that participated in Bebras in Germany showed that more female than male students opted to work in pairs, and that pairs of either gender were more successful than students who participated individually (Hubwieser et al., 2016).

5.3 Elements to engage young female students - task content

The literature review component of this report highlighted the importance of task content in engaging female students in digital technology programs, with real-world issues and non-traditional contexts associated with increased reports of engagement in young female students. Early engagement for sustained participation is also important given young female students' declining engagement with digital technology in early adolescence (Spieler et al., 2020). Inclusion of tasks that stimulate the interests of female students should continue to be transparent in the programs. A research evaluation of Bebras in Germany showed that female students were found to perform better in a given task if the tasks were visually appealing and represented a real-life situation relevant to the students (Hubwieser et al, 2016). Evaluation of the US CyberPatriot program showed that female students were more likely to sign up for the program based on their individual interests or aspirations whereas males' participation was more likely to be influenced by gaming being a shared interest in their peer group (Brough, 2016. Given the emphases in the literature review of the importance of peer collaboration and shared experiences for female students, this finding suggests that ensuring the culture of digital technology is more inclusive of female students and that negative stereotypes around female gamers are identified and dismantled, is crucial for gender equity in digital technology engagement. Incorporating real-world issues relevant to student's lives and aspirations in the development of supporting resources for Bebras, CyberTaipan and Microsoft FarmBeats is another avenue through which this inclusivity can be developed.

5.4 Incorporation of diverse contexts

Research suggests that the cultural diversity of a nation's workforce is important for innovation and for enhancing a nation's competitive stance in the global economy. There is limited availability of information relating to how Bebras, CyberTaipan and Microsoft FarmBeats incorporates diverse contexts relating to the Australian context. Results from CyberTaipan 2021 participation information showed that 1.5% of participants identified as Australian First Nations peoples. A recent study identified intentionality as a key strategy for facilitating successful outcomes for minority students' engagement with STEM, where intentionality is the process of shaping content to be inclusive of student diversity by appreciating student differences in cultural, social, financial and academic areas (National Academies of Sciences, Engineering, and Medicine, 2019). To successfully engage and sustain First Nations students' involvement in CEdO Digital Careers programs, an intentional strategy to engage and support students is required.

6 Recommendations

This section of the report offers a set of recommendations for the Digital Careers team that are aimed at increasing the participation of young female students in their CEdO digital education programs. These recommendations build on the literature, policy and program reviews presented in the previous sections of the report. During ACER's communication with CSIRO through the course of Part 1 of this project, it was clear that the Digital Careers team bring expertise, passion and dedication to the management of the CEdO programs. The recommendations made by ACER are designed to enhance the great work that has already been established. ACER offers an external perspective for ways to increase female students' participation in CEdO programs and the Digital Careers team can determine whether the recommendations made fit within the team's approach to managing each program.

ACER's recommendations are separated according to those that can be acted on now, those that could be achieved in the short-term and those that are long-term goals. Some of the recommendations that can be acted on now include a set of ACER-developed brief, informational resources for teachers on key issues. ACER will develop these resources and suggests that they are distributed to digital technology teachers and school leaders participating in CEdO programs so that they can be used to inform teachers' classroom practice. Digital technology teachers that use these resources will be better able to identify, discuss and break down key barriers to female students' engagement leading to improved attitudes towards digital technology. Consequentially, it is hoped that the Digital Careers team will see increased participation of female students in their programs.

All recommendations are listed in Table 3 and then expanded on below.

Table 3 Summary of recommendations for the Digital Careers team

CATEGORY	RECOMMENDATION
Recommendations that can be acted on now	1. Expanding the locations where CEdO programs are advertised and promoted (e.g with DATTA Vic, DATTA Queensland, QSITE and ICTENSW) 2. Engaging parents through participation (e.g. as Bebras Coordinators) and by linking to cybersafety resources (see resources developed by the e- safety Commissioner: https://www.esafety.gov.au/kids) 3. Developing brief information sheets for teachers about the impact of parental cybersafety concerns on digital technology access and participation (ACER to develop) 4. Developing brief information sheets for teachers to better engage female students (ACER to develop) 5. Developing brief information sheets for teachers to address stereotypes and stigma (ACER to develop).
Recommendations for the short-term	1. Curriculum mapping programs to the content descriptions of the Key Learning Areas and continua of the General Capabilities of the Australian Curriculum. 2. Enhancing the role of mentors and expanding mentor recruitment strategies (e.g. considering remote mentorship options, recruiting through the STEM Professionals in Schools program with organisations such as Data61, and inviting university students completing digital technology programs to be mentors)

	3.	Expanding the representation of young female students and students from diverse backgrounds in visual imagery associated with CEdO programs (e.g. in newsletters, on social media platforms and in publications like the annual report)
	4.	Reviewing task content, where possible (e.g. within the constraints of each program, examining ways that task content could be modified to be more inclusive)
	5.	Investigating current gender stereotypes and stigma around females and digital technology in Australian early adolescent peer culture to enhance and refine resources developed to dismantle these negative attitudes
	6.	Partnering with First Nation businesses and communities (e.g. the Indigenous Digital Excellence (IDX) Initiative, InDigiMOB, Willyama and Baidam).
Long-term recommendation	1.	Building new supporting resources for Bebras that are more inclusive for all students, are aligned to the Australian Curriculum, build student confidence and engagement, and scaffold students into participating in the Bebras competition rounds.

6.1 Recommendations that could be acted on now

6.1.1 Expanding the locations where CEdO programs are advertised and promoted

ACER notes that the Digital Careers team has a wide range of channels through which they advertise their management of Bebras, CyberTaipan and Microsoft FarmBeats. Additional avenues that could be explored to increase the visibility of the programs and their value include through teacher association websites and professional bodies such as DATTA Vic, DATTA Queensland, QSITE and ICTENSW. In particular, ICTENSW runs conferences and workshops which could be ideal for the promotion of the Bebras, CyberTaipan and Microsoft FarmBeats programs.

6.1.2 Engaging parents through participation and by linking to cybersafety resources

Both in the literature review and in the review of the alternative program, Digital Youth Divas, the benefit of engaging parents as partners in the digital education process was emphasised. Unfortunately, there seems to be limited scope for all parents of participating students to be involved in the CEdO programs. Parents could be encouraged to take on coordinator roles for Bebras where relevant.

6.1.3 Developing brief information sheets for teachers about the impact of parental cybersafety concerns on digital technology access and participation

A clear finding in the literature review was the barrier that parental cybersafety concerns can have in determining female students’ access to digital technology. This may also impact on female students’ uptake of CEdO programs in primary school and their sustained engagement with the programs in early secondary school. Providing links to cybersafety resources for parents and emphasising where programs like CyberTaipan provide training in cybersafety skills would be advantageous. The resources provided by the e-safety Commissioner could be linked to when advertising the programs (https://www.esafety.gov.au/kids). ACER will also develop a brief, informational resource for teachers to outline the barrier of parental cybersafety concerns and how this might be discussed in the classroom.

The literature review also outlined cybersafety as a critical issue for First Nations students in Australia with research showing they are at an increased risk of online abuse, cyber-bullying and image-based abuse (NIAA, 2021). Explicit tools to support respectful online engagement in culturally safe and appropriate ways may support the engagement of First Nations students with CEdO programs as well as young female students in general. The e-safety Commissioner's website provides guidance resources specifically for First Nations peoples (https://www.esafety.gov.au/diverse-groups/aboriginal-and-torres-strait-islander-peoples).

6.1.4 Developing brief information sheets for teachers to better engage female students

ACER recommends developing a brief information sheet for digital technology teachers that requires them to reflect on the impact of task features (e.g. task content and contexts, opportunities to collaborate with peers) on students' engagement in digital technology, in particular to female students' attitudes and enjoyment of the subject. ACER will develop this resource during Part 1 of this project.

6.1.5 Developing brief information sheets for teachers to address stereotypes and stigma

ACER suggests developing a brief information sheet for digital technology teachers that outlines stereotypes and stigma around young female students and the digital technology field, for example, 'girls and gaming'. This is needed so that teachers can identify these stereotypes in themselves and their students. This resource would also provide teachers with strategies on how to challenge these stereotypes in their classroom and ways to make their classroom culture more inclusive. ACER will develop this information sheet as part of the resources created for Part 1 of this project.

6.2 Recommendations for the short-term

6.2.1 Curriculum mapping

ACER suggests that explicit mapping of supporting Digital Careers resources to the content descriptions of the Key Learning Areas and continua of the General Capabilities of the Australian Curriculum (AC) will provide teachers with clear opportunities to include the resources in classroom contexts, exposing students to the programs and competitions and the opportunities afforded by participation. The revised curriculum (v9.0) will provide further opportunity to map Bebras 365 and CyberTaipan support materials to the curriculum, with v9.0 including explicit content descriptions to support student learning about privacy and security in Digital Technologies. It is possible that this could be achieved before Round 2 of Bebras begins in August 2022 by members of the CEdO team.

The professional development proposed to support uptake of Microsoft FarmBeats is another critical opportunity for teachers to understand the alignment of the program to the AC and further develop their digital skills. More generally, the Digital Career team's focus on professional learning in 2022 could also be an opportunity to highlight the key barriers and enablers to female students' engagement with digital technology in professional learning sessions.

6.2.2 Enhancing the role of mentors and expanding mentor recruitment strategies

ACER proposes enhancing the role of mentors and industry experts that support the CEdO programs would likely increase student participation in the programs and engage young female students through exposure to role models. CSIRO may be able to leverage from other programs, such as STEM Professionals in Schools that have implemented these types of practices in order to increase the engagement of female students. Remote mentorship may be an effective strategy and potentially extend the reach of support to students in rural and remote areas. Research has suggested that female students value online support options such as tutoring sessions and collaborative group meetings, and choose to participate in this online support for longer periods and more frequently than their male peers (Spieler et al., 2020; Spieler, 2021). Where possible with funding constraints, the CEdO programs could also promote and incentivise the opportunity for students to participate in teams, especially all- female teams.

Obtaining a large number of mentors can be a difficult challenge. Besides the STEM Professionals in Schools program, CSIRO could also look at asking researchers at Data61 to act as mentors, as well as teachers from the various digital technology and computer science associations across Australia. University students enrolled in digital technology courses may also wish to act as mentors, and this could be particularly beneficial for senior secondary students given the success of near-peer mentoring in the AspireIT program.

6.2.3 Expanding the representation of young female students and students from diverse backgrounds in visual imagery associated with CEdO programs

As outlined in the review of alternative digital technologies programs, narratives and stories that show female role models in relevant, local contexts can increase the engagement of female students (e.g. in the She Maps program, Digital Youth Divas and Girls Who Code). Increased representation of young female students and students from diverse backgrounds participating in CEdO programs – for instance in newsletters, on social media platforms and in publications like the annual report – could lead to increased participation of female students and female teachers in these programs. The Digital Careers team could invite all-female teams and teams with students from diverse backgrounds to submit photos of their groups that could be posted in various publications once the requisite permission had been received by all relevant parties.

6.2.4 Reviewing task content, where possible

Further evaluation of how the tasks for Bebras, CyberTaipan and Microsoft FarmBeats are reviewed should consider how they could be modified to be more inclusive. ACER notes that there is limited scope to change the tasks, particularly for Bebras and CyberTaipan, and that the Digital Careers team currently adapts these tasks to be as inclusive as possible within the constraints of these international programs. Feedback from teachers involved in Microsoft Farmbeats suggests that through program participation students develop a better understanding of technology applications in the real world. This was observed for agricultural tasks that explored climate change and food security and tasks that examined the social and ethical implications of artificial intelligence. Consideration should be given to build on this momentum and develop further tasks that are relevant to students lives (e.g. domestic issues relating to climate change, such as floods, drought and changing average temperatures) and engaging to young female students and allow their interests to be validated, cultivated, and aligned with new opportunities. Strategies to engage the participation of young female students should consider their interests and aspirations to ensure the value of participation in the programs is apparent.

6.2.5 Investigating current gender stereotypes and stigma around females and digital technology

Research is needed to investigate the type and extent to which stereotypes around females engaging with digital technology are present in Australia, particularly in early adolescent peer culture. This research should also examine whether these stereotypes differ among groups (e.g. for First Nations students, for students in rural and remote areas, and for students from more disadvantaged backgrounds). ACER will incorporate this into the design of the research project that will be conducted in Part 2 of this project. Findings could also be used to enhance and refine the information sheet developed for digital technology teachers on gender stereotypes and stigma developed for Part 1 of the project.

6.2.6 Partnering with First Nation businesses and communities

Many of the strategies recommended in this report to engage female students in digital technology programs need to be considered in the context of First Nations peoples in Australia. Collaborations with First Nation community organisations may provide support in engaging First Nations students with the CEdO programs and demonstrate relevant career opportunities that benefit all Australian communities. Further, an increased profile of First Nation organisations specialising in emerging technologies, artificial intelligence and cyber security services in the CEdO space (for instance, as mentors to the programs) could help to demonstrate the relevance and opportunity to First Nations students of career paths in these areas. Engagement with family and community groups can not only bring layers of support for First Nations students, but also provide insight into contexts and issues that are of relevance and interest to these students.

As an example of partnering, the Indigenous Digital Excellence (IDX) Initiative is a strategy co-founded by the National Centre of Indigenous Excellence (NCIE) and the Telstra Foundation. It is focused on driving First Nations peoples' digital engagement in Australia. IDX supports a range of activities including workshops that bring together First Nations peoples from multiple communities across Australia to share experiences and build skills and connections that will benefit their communities. Resources developed for the IDX are culturally responsive and a priority of the program is ensuring young students are linked with one another via various platforms as well as connected to their Elders, families and communities. The IDX may be an ideal initiative to connect with to advertise the CEdO programs as well as for recruiting First Nations mentors. Some other examples of potential partners include InDigiMOB, Willyama and Baidam.

6.3 Long-term recommendation

6.3.1 Building new supporting resources for Bebras

ACER notes that the immediate and short-term strategies recommended for increasing female students' participation in CEdO programs have all been addressing this issue from a deficit perspective. This is necessary in the short-term to help students who are currently at academic transition points where they are making decisions about whether to consider studying digital technology in the senior secondary school years and/or to pursue a career in the area. The resources developed from this deficit perspective are focusing on what is lacking for female students and other disadvantaged groups, and what can be done to address this and build engagement. However, taking this stance means disregarding the larger issue; that is, what is the culture of the existing dominant group and how does this exclude newcomers?

ACER believes that there is an opportunity to develop a new set of teaching resources based on a strengths-based philosophy. These resources would be developed by targeting dominant culture around digital technology and highlighting what is consciously or unconsciously exclusionary so that the educative field of digital technology is more inclusive for all students. ACER suggests that a set of new teaching resources to support Bebras may provide the most scope for achieving these goals given the program starts in the early primary years and progresses through to senior secondary school. These resources would be used by teachers as classroom activities to build student confidence and engagement in digital technology and also scaffold students into participating in the Bebras competition rounds. They would involve contexts that are more inclusive of the experiences of First Nations and rural and remote students, and the interests of female students as well as incorporating features that lead to greater engagement for female students. Explicit alignment of these resources to the Australian Curriculum will facilitate their use in schools. These resources could also be a source of professional development for digital technology teachers and ensure that educators are playing positive roles in engaging young female students in the field.

Should CSIRO be interested in this recommendation, ACER has the staff expertise and capacity to work collaboratively with the Digital Careers team to develop these resources.

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