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Towards a socio-ecological framework to address gender inequity in computer science

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ABSTRACT

In Australia the under-representation of women in computer science reflects the under-representation of women at the highest levels of government and business. In this paper we argue, therefore, that change is going to require a cohesive multi-level analysis and intervention approach. To illustrate how such an approach might look, we draw on social psychologist Uri Bronfenbrenner's socio-ecological systems theory to analyse a national survey with secondary school computer science teachers we conducted in 2017. By employing this analysis we can see that student interest and engagement in computer science is impacted by their teachers, peers and parents (microsystem) who sit within a wider community, educational and industry network (mesosystem) which in turn is influenced by their access to relevant human and physical infrastructure (and the policies that shape it) in their school and social environments (exosystem) and by the broader values and rhetoric around gender and Digital Technologies in the wider Australian community (macrosystem).

1. Introduction

Social change in gender relations is slow in Australia. Positive signs include the first season of the Australian Football League (AFL) women's competition in 2017; 57.9% of university students are female (Universities Australia, 2017); workforce participation by women has increased to 46.2%; and women currently comprise 32% of the Federal Parliament (Hough, 2016). Less encouraging is that the gender pay gap sits at 15.3% and has remained between 15% and 20% for twenty years (Workplace Gender Equality Agency, 2017), and only 25.4 percent of Australian Securities Exchange (ASX) 200 companies have female board members when a critical mass of 30% is needed for the benefits of gender diversity to be realised (Australian Institute of Company Directors, 2017). Data from the Global Institute for Women's Leadership (2018), based in King's College, London, and chaired by Julia Gillard, former Prime Minister of Australia (2010–2013), shows that Australia is not unusual. Across the globe, women comprise just 23% of politicians, 26% of leaders in the media industry, 27% of the judiciary, 25% of senior executives, 15% of company board members, and only 9% of the leadership of the Information Technology industry.

This slow social change is reflected in the gender divide in enrolment trends in Digital Technologies courses. In 2014 the Australian Federal Government introduced its first national Digital Technologies curriculum, an initiative which complements significant work by universities and industry leaders over many years to grow the number of domestic student computer science enrolments. While the investment has paid dividends with an increase of 67.9% in enrolments between 2008 and 2015, the

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percentage of domestic female enrolments has declined from 17% of the total in 2008 to 14% in 2015 (Falkner, 2017; Falkner, Szabo, Michell, Szorenyi, & Thyer, 2015; Rosa & Tudge, 2013) and women continue to be underrepresented in the computer science industry across Australia (Zagami, Boden, Keane, Moreton, & Schulz, 2015).

Because the under-representation of women in computer science reflects the under-representation of women at the highest levels of government and business in Australia (Australian Institute of Company Directors, 2017), in this paper we argue that change is going to require a cohesive multi-level analysis and intervention approach. To illustrate how such an approach might look, we draw on social psychologist Uri Bronfenbrenner's socio-ecological systems theory to analyse a national survey with secondary school computer science teachers we conducted in 2017. Bronfenbrenner's theory breaks human development into four key systems—the macrosystem, the exosystem, the mesosystem and the microsystem—where each system is connected and the macrosystem is the key influencer. It is an especially useful method for examining the "nested and complex relationships among the various systems of human development" (Basham, Israel, & Maynard, 2010, p. 11). From analysis of the data we can see that student interest and engagement in computer science is impacted by their teachers, peers and parents (microsystem) who sit within a wider community, educational and industry network (mesosystem) which in turn is influenced by their access to relevant human and physical infrastructure (and the policies that shape it) in their school and social environments (exosystem) and by the broader values and rhetoric around gender and Digital Technologies in the wider Australian community (macrosystem).

Australia is far from the only country where women are under-represented in computer science (Zweben & Bizot, 2014). As pointed out above, across the globe women represent only 9% of senior leaders in the Information Technology industry (Global Institute for Women's Leadership, 2018). Therefore the paper begins with an overview of the many attempts that have already been made to address this imbalance. We then examine Bronfenbrenner's theory in more detail and demonstrate how a multi-level analysis draws attention to where interventions are most needed and how all system levels must make an investment in increasing gender and other forms of diversity in Digital Technologies.

2. Background on gender & computer science

There is a considerable volume of research into the longstanding problem of the under-representation of women in computer science. Much of this has tended to employ three "deficit models": deficits in women (women's lack of interest, experience or skills); deficits in computer science teaching (lack of appropriate pedagogical techniques) and deficits in the "image" of computer science (perception of masculine space and lack of inclusion (Lagesen, 2011)). Interventions, therefore, seek to correct these deficiencies, many of which have attempted to solve the problem in ways that are themselves based on gender stereotypes, such as efforts to emphasise the so-called "feminine" aspects of computer science by presenting it as requiring skills in teamwork and communication, efforts that young women already studying computer science find irrelevant, if not patronising (Lagesen, 2011).

Many attempts have been made to increase teenage girls' interest, experience or skills in computer science. These include exposing them to female computer science teachers and role models (Beyer, 2014), code clubs and awareness events (Craig, Lang, & Fisher, 2008; Klawe, Whitney, & Simard, 2009; Lang, Fisher, Craig, & Forgasz, 2015; Sorensen, Faulkner, & Rommes, 2011), computational textiles to teach programming (Qiu, 2013), fashion design (Lau, Ngai, Chan, & Cheung, 2009), and using computer games (Jill Denner, 2011; Jill Denner, Werner, Bean, & Campe, 2005; Jill Denner, Werner, & Ortiz, 2012; Papastergiou, 2009). Efforts have also been made to engage with parents to address concerns about and misconceptions of the industry (Zagami, Boden, Keane, Moreton, & Schulz, 2016; Zagami et al., 2015). Many such programs have generated increased interest by girls in computer science, but the interest has not necessarily translated into increased participation by women in university programs (Craig et al., 2008; Lang, Craig, & Egan, 2016; Lang et al., 2015) (also see Beyer, 2014; Miliszewska & Sztendur, 2010). Another concern is that some activities serve to reinforce gender stereotypes, such as engaging girls' interest through fashion design.

Because of a concern that adolescence is too late to be engaging girls, experiments in North America are now being conducted at primary schools to provide girls with computer science experiences designed to increase both their interest and self-efficacy, with mixed results. For example, Amanda Sullivan's recent study shows that after undertaking robotics classes for 7 weeks, girls as young as 5–7 were significantly more likely to say they would enjoy engineering as a career. In Lucy Heacock's study of 40 primary school female students, the majority valued science, were confident in their scientific abilities, and most expected that science would feature in their futures. Yet only a minority had determined they wanted to be scientists (Heacock, 2016).

Considerable attention has also been paid to the stereotype of computer science as a "masculine" domain (Margolis & Fisher, 2003; Michell, Szorenyi, Falkner, & Szabo, 2017; Michell, Szorenyi; Trauth, Nielsen, & Von Hellens, 2003; Wacjman, 2001) and to the problems of stereotype threat and sub-typing. Based on the work of social psychologist, Claude Steele (2011), stereotype threat is the idea that an individual's academic performance may be adversely affected by their desire to not confirm a negative (gender, race or class) stereotype, and subtyping occurs when women in computer science are subtyped as "female" computer scientists rather than simply as computer scientists, which creates a separation between the computer scientist and the female computer scientist, thus further entrenching the stereotype of computer scientists as male (Betz & Sekaquaptewa, 2012; Patitsas, Craig, & Easterbrook, 2015, pp. 61–69). Cheryan, Master, and Meltzoff (2015) have explored stereotypes in the North American context and argue that stereotypes about the people (unsociable), about the work (competitive rather than collaborative), and about the individualistic self-reliant masculine values of the field, combine with a general sexist stereotype that boys have more ability than girls. These stereotypes affect girls early and are transmitted through television and movies (Master & Meltzoff, 2016; Master, Cheryan, & Meltzoff, 2017; Master, Cheryan, Moscatelli, & Meltzoff, 2017); American children as young as six already hold stereotypes that boys are better suited to computer science (and other STEM subjects, see Betz & Sekaquaptewa, 2012) when they enter school (also see Stoilescu & McDougall, 2011), and are often more prepared through play with technology to engage in computer science (Gokhale, Rabe-Hemp, & Woeste, 2015).

Attempts to ameliorate the negative impact of stereotypes on girls (and students of colour, see Joanna Goode & Margolis, 2011) have also been in effect for some years. These include changes to the design of the pre-university curriculum to make it more culturally relevant to a diverse group of students (Goode & Margolis, 2011; Goode, 2008) and university classrooms (Cheryan, Meltzoff, & Kim, 2010; Gherardi & Poggio, 2001) so that—whether the classrooms are brick and mortar or virtual—they do not conform to prevailing computer science stereotypes but give women a sense of "ambient belonging" and increased fit with their social identity. Such changes have resulted in more women enrolling in a course and no fewer men (Cheryan, Drury, & Vichayapai, 2012) although in one study women who felt they fitted the stereotype of a computer scientist, preferred the stereotypical classroom environment (Master, Cheryan, & Meltzoff, 2015).

Negative stereotypes are not universal, however, and this demonstrates the need to examine how the macro or cultural level influences what happens in schools and home. In India, for example, computer science is regarded as a prestigious "woman-friendly" profession and computer scientists as intelligent and sociable (Varma & Kapur, 2015, p. 59). Women are often encouraged to begin studying computer science by male family members and are motivated to continue because their standing in the community is elevated and the prospect of a well-paid job gives them a sense of independence (Varma & Kapur, 2015, p. 58; also see Cheng & Huang, 2016; Fan, 2005; Gharibyan & Gunsaulus, 2006, pp. 222–226; Othman & Latih, 2006; Singh, Allen, & Scheckler, 2007 for other cultural variations).

Values and beliefs at the macro or cultural level will also influence the gender culture of government, business and other organisations. In other words, organisations, like individuals, "do gender" (West & Zimmerman, 1987), meaning that organisations "presuppose a set of already hierarchically normed interactions based on the sexual division of labor and on gender expectations" (Gherardi & Poggio, 2001; Gherardi, 1996, p. 257) and individuals are expected to acquire the skills to "fit" in (Gherardi, 1994). Studies highlight the additional gendered and often invisible work—and therefore energy and resources—women in male dominated industries, including computer science, need to expend outside of the formal job requirements in order to both fit in and resist gendered norms (Powell, Bagilhole, & Dainty, 2009; Pretorius, Mawela, Strydom, de Villiers, & Johnson, 2015; Smith, 2013) as well as the strategies women employ to survive and thrive in Computer Science (Hodari, Ong, Ko, & Smith, 2016; Jin, 2007).

All this research suggests the need for research and interventions at multiple levels of society, but also that evidence based interventions have to date unfolded in a somewhat ad hoc manner rather than being specifically planned. What we suggest with this paper, and based on a national survey of secondary teachers in Digital Technologies, is a coordinated plan of interventions at multiple levels of the Australian community, based on an adaptation of Urie Bronfenbrenner's ecological systems theory of child development and with an emphasis on gender (see also the similar call by Jewkes, Flood, and Lang (2015) to address the longstanding issue of violence against women).

3. Socio-ecological framework for analysis of computer science education

Urie Bronfenbrenner's ecological systems theory of child development theory was influenced by environmental biology (Bond & Pyle, 1998) and developed from his questioning of research with children that disregarded the child's environment or viewed it as static (Bronfenbrenner, 1975, 1986). Bronfenbrenner stressed the need to consider more than the researcher and the child, to also consider the *context* in which the child was situated, that is, the dynamic interactions between people and their environments which are both physical and social (Bahns, Pickett, & Crandall, 2011; Bond & Pyle, 1998). These interactions can be analysed at multiple levels—microsystem (individual, family); mesosystem (relationships between multiple microsystems); exosystem (influencing systems that affect but do not contain an individual); and macrosystem (over-arching socio-cultural values and beliefs), all of which constitute an "ecological system that included the developing individual" (Rosa & Tudge, 2013, p. 246). According to Bronfenbrenner, researchers also need to consider that environments change over time and place (Bronfenbrenner, 1995; Rosa & Tudge, 2013), and that there is an ongoing interaction between the "developing and the changing micro and macro context" (Rosa & Tudge, 2013, p. 246). While Bronfenbrenner was interested in the effect of the environment on the individual in their development, he was also interested in how the individual in turn shaped their environment, hence his use of the word *ecology* to denote this interaction (Bond & Pyle, 1998; Bronfenbrenner, 1995; Rosa & Tudge, 2013).

Bronfenbrenner's ecological theory has been used for many years and in a wide range of applications. For example, in exploring adolescent career development (Young, 1983), workplace diversity (Bond & Pyle, 1998); to argue for similarities between higher education and online gaming (Herz, 2002); to examine the use of domestic service robots (Forlizzi & DiSalvo, 2006, pp. 258–265); the dissemination of computer science information (Shi, Tseng, & Adamic, 2009, pp. 319–322); STEM education for students with disabilities (Basham et al., 2010); formation of friendships (Bahns et al., 2011); bullying (Jamal, Bonell, Harden, & Lorenc, 2015; Schumann, Craig, & Rosu, 2014); and health in the LGBTQ community (Mink, Lindley, & Weinstein, 2014).

Multi-level analyses have also been explored by sociologists to specifically examine gender as an organising principle (see for example Lorber, 1994; Ridgeway & Correll, 2004; Risman & Davis, 2013; Risman, 2004, 2009) and the ways in which individuals are both constrained by and resist the constraints of social structures (see for example Giddens, 1984). Bronfenbrenner's ecological approach has been blended with these sociological theories of gender analysis, for instance, Barbara Risman's individual, interactional and institutional level analysis of the gender structure, as used by Legerski and Cornwall (2010) in investigating gender and housework; Armstrong, Hamilton, and Sweeney (2006) in interrogating sexual assault on college campuses; and in calls to implement multi-level interventions to prevent violence against women and girls (Jewkes et al., 2015). As Jewkes et al. (2015) point out, ecological approaches enable understandings of what supports existing social norms because "masculinities are embodied and reproduced across the social ecology, and thus interventions must seek changes at multiple levels" (Jewkes et al., 2015, p. 14). It is difficult, as Armstrong et al. say (2006, p. 496), "to enact change at one level when the other levels remain unchanged", as is borne out by the extensive research on the intransigent problem of the under-representation of women in Computer Science.

By using Bronfenbrenner's ecological systems theory and combining it with Risman's (2004, 2009; Risman & Davis, 2013) gender structure theory, we can explore how gender is embedded and enacted at these multiple levels, as well as how/where it might already being "undone"—that is, where the "essentialism of binary distinctions between people based on sex category is challenged" (Risman, 2009, p. 83 p. 83)—and what interventions are needed to further dislodge unequal gender relations. In arguing for such a multi-level analysis we are not saying that there are clear distinctions between each one as we recognise that these levels "operate continually and reciprocally" in our daily lives (West & Fenstermaker, 1995, p. 24). Rather it is a way by which we can analyse the need for, implement, and monitor multi-level interventions.

4. Methods

We designed and distributed an electronic survey to secondary school teachers throughout Australia. The survey aimed to collect broad, quantitative data on three aspects of Digital Technologies teaching in secondary schools: what curriculum, policies and resources are already in place in schools to support Digital Technologies teaching and learning and what more teachers feel is needed; whether gender (and other forms of) diversity in teaching are perceived as an issue by teachers; and if so, what teachers do to address this issue. The survey was run during two periods, from 1st March to 15th May 2017 and again (due to low response rates) from 15th June to 20th July, and distributed to each state and territory through the teacher professional associations of each state and territory. We received 65 responses to 49 questions, with a total of 1885 quantitative responses and 1289 open-ended textual responses. Of the 65 participants, 60% were female. When it came to age, 39% were 25–40 years old, 48% were aged 41–55, and 13% were 55 or over. The participant schools were spread over most Australian states: Australian Capital Territory (6.2%), Victoria (13.8%), South Australia (23%), Tasmania (4.6%), Northern Territory (1.5%), New South Wales (16.9), Queensland (20%) and Western Australia (13.8%), with percentage distribution mostly representative of the school distribution across Australian states: Australian Capital Territory (2.1%), Victoria (25%), South Australia (7%), Tasmania (8%), Northern Territory (2.3%), New South Wales (27%), Queensland (18%) and Western Australia (10%) (ACARA, 2016). There was a nearly even split between state (government funded) schools (50.76%) and independent (combined parental fees and government funding) schools (49.23%), a ratio smaller than the Australian ratio of 60/40 (ACARA, 2016).

We performed a quantitative analysis of responses and the initial qualitative analysis was guided by grounded theory. Grounded theory involves the establishment of a coding framework and analysis environment derived from the data itself rather by themes from research literature (Urquhart, 2013). In a first step, we performed open coding by reading through the open-ended responses, and tagging blocks of text representing a concept related to teaching computer science or to diversity in the computer science classroom. As a final step, we matched these themes against Bronfenbrenner's multi-level model.

5. Analysis using a socio-ecological framework

5.1. Macrosystem

The macrosystem is the system of cultural values and beliefs, historical events and political objectives that shape educational priorities (Basham et al., 2010; Young, 1983). The belief system at this level is over-arching and therefore the experiences of most children are similar (Rosa & Tudge, 2013, p. 247). Applying a macrosystem lens to Digital Technologies in Australia means looking at the ways national rhetoric shapes the student experience of, and engagement with, both gender—that is, the "social values, roles, behaviours, and attributes considered appropriate and expected for men and women" (Jewkes et al., 2015, p. 5) (also see Risman, 2004)—and Digital Technologies.

We have already suggested that crucial aspects of gender organisation are resistant to change in Australia despite more than 40 years of feminist activism, such that male domination of public life and some industries continues. A national conversation about the place of Digital Technologies in Australia is more recent: in response to declining interest and a national economic need, in 2014 Australia introduced its first national Digital Technologies curriculum intended to provide students with practical opportunities to use design thinking and to be innovative developers of digital solutions, and which recognised the need to encourage more girls and women into the field (Turnbull, 2015). At the end of 2015, the Federal Government launched a new National Innovation and Science Agenda (Turnbull, 2015) and followed that twelve months later with a statement that the government is "investing $112 million to inspire all Australians, from pre-schoolers to women and the broader community, to engage with science, technology, engineering and maths" (Turnbull, 2016) while also recognizing that the three groups still under-represented at university—Indigenous Australians, those from low socio-economic backgrounds, and rural/regional students (Bradley, Noonan, Nugent, & Scales, 2008)—are also underrepresented in STEM. In other words, the Federal Australian Government is aware of the need to promote STEM at all levels of the community, and with a specific focus on women and other underrepresented groups.

Government policy, however, is not the same thing as national culture. While there is some national or macro-level conversation happening about gender inequity in STEM and in computing, we have already pointed out the low and declining percentage of female computer science enrollees. These low figures of female representation are reflected in our survey results: a majority (83.92%) of co-educational school teachers—86.2% of participants were from co-educational schools, representative of Australian secondary schools—had elective Digital Technologies classes where female students were either very few (less than 10%) or a minority (10–20%). The key reasons for the lack of gender diversity as identified in participant responses are the perception that female students lack a positive computer science experience (either in primary school or within their peer group) and therefore do not see it as a discipline worth pursuing; stigma associated with the discipline; and intimidation experienced by female students and one teacher in Digital Technology classes dominated by male students. In contrast to the Prime Minister's call for more Indigenous, rural/remote and low socio-economic status background students in STEM, the majority (84.6%) of survey participants responded "no" when asked if they saw any other diversity issues within their classrooms.

In summary, at the macro or cultural level of Australia there is a recognised need for more inclusivity in Computer Science, but this has yet to translate into more female computer science students in Australian schools.

5.2. Exosystem

The exosystem describes the interconnected national, state and local systems that react to the cultural, economic and social values and beliefs at the macro level and includes socioeconomic status, parental employment and networks, public policy about education, and the media. These systems affect students but do not *directly* contain them (Basham et al., 2010, p. 13). For example, what happens in the parent's workplace affects children and young people (Rosa & Tudge, 2013) as do parental friendship groups (Young, 1983). Another example is that high school students are influenced indirectly by universities via university-trained teachers and outreach to school teachers by academics (Basham et al., 2010).

In examining the exosystem, we would be looking for policies, practices and programs that support the Federal Government's intention to create a nation of digitally-skilled citizens. For example, the Office for Women, located in the Department of the Prime Minister and Cabinet and having as its mission to provide "strategic policy advice and support to the Prime Minister and the Minister for Women" has several initiatives in place to support women in the broader area of STEM, with two scholarships provided to senior executive women working in STEM industries (Office for Women, 2017). (The national online media output that uses academic content, *The Conversation*, has also contributed 19 articles since 2011 on the topic, including examining stereotypes of the Computer Science industry but we have not yet analysed other media buy-in to this discussion).

A strong and diverse digital technologies exosystem requires state, school and community networks that see digital technologies as a relevant and serious subject and that encourage and support (financially and otherwise) teachers to work toward increasing equity (gender and otherwise) in their classes. From our survey data, we found that most teachers (69.56%) thought that computing equipment was sufficient for teaching digital technologies, so this suggests a significant investment nationally (Fig. 1).

A third of participants were requesting further investment in specific equipment, such as robotics, EV3, Arduino, RaspberryPi etc. (n = 8), another computer lab or more computers to service the school (n = 5), a dedicated lab (n = 4), reliable Internet access (n = 3), dedicated storage space (n = 2), and newer computers (n = 2).

When it came to diversity training and support, however, 52.30% of respondents said they were not encouraged to pursue diversity issues in their classrooms (including gender). Moreover, nearly 28% of teachers reported either having had no training with respect to diversity, or were self-taught (e.g., attending an Aboriginal cultural awareness workshop), while the remainder reported teacher training or professional development workshops as the main sources of information. As well, resources for encouraging diversity were inadequate, with 56.92% of respondents wanting more workload time (14.34%), training (11.88%), teaching assistants (10.24%), as well as more or different physical teaching spaces (9.01%), and more industry outreach engagement (9.42%).

In response to the question about how participants would use increased resources to address diversity, the majority (40.35%) were unsure, which highlights the lack of diversity training outlined above. For the remainder, our qualitative analysis identified three main themes: promotion of the discipline; changing teaching practices; and the use of role models to encourage more female students.

Although promotion of computer science was regarded as important to increase diversity, only 37% of teachers felt they had enough knowledge and resources to promote a career in digital technologies to high school students, and only 26.13% of participants reported that they have industry visitors within their school. Most of the participants who were not engaging with industry partners were unaware of the possibilities or did not have any partner contact. Other reasons for lack of contact with industry included lack of time, or the fact that the school is not in a metropolitan area (or is rural/remote) thus making it difficult for partners to travel. Other concerns included the lack of support from the school, as one participant notes: "*Digital Technology is a new subject at my school: 2016*

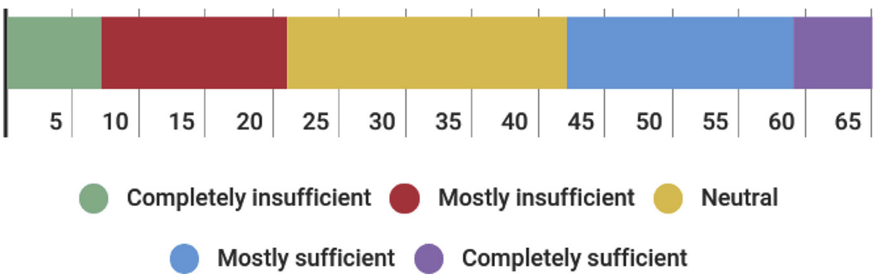

Fig. 1. Computing Resources are Mostly Sufficient for Teaching Digital Technologies.

was the first time it was taught … Lack of expertise and direction by line manager. The school has not invested time or money in upskilling teachers to teach this subject. Lack of teacher expertise is a major area of concern." (Table 1)

Table 1
Reasons for the lack of engagement of industry partners.

Key Themes	Mentions
Unaware of possibilities	14
Lack of contacts/partners	8
Location too remote/rural	6
Lack of time	6
Difficult to fit in lessons	4
Did not feel it was necessary	4
Lack of support from school	1

A majority of respondents (70%), however, responded in the affirmative when it came to student participation in extracurricular digital technology activities. The most mentioned competition or outreach program was First Lego League (40% of mentions), followed by Code Club (20%) and RoboClub (13%) and, with three or less mentions, Young ICT Explorers (2 mentions), Grok (3), NCSS (3), First Robotics Competition (3), iAwards (1), Robogals (2), Tech Girls are Superheroes (2), NCSS (3), CSIRO ICT in Schools (1).

These results suggest key areas of intervention required are more training and resources to increase diversity, and more school-industry engagement in CS classrooms to promote the discipline.

5.3. Mesosystem

The mesosystem refers to the complex interactions *between* the microsystems that have *direct* influence on students (Basham et al., 2010, p. 14). One example is transition—between home and school, from school to work, from school to university, from university to paid work. Another is ensuring that students have what they need at home to support their work at school, as in the "STEM for all" project where "digital backpacks" were provided to students (Basham et al., 2010).

An analysis of mesosytems thus involves looking at whether microsystems align or clash with one another. From a previous study we have an example of how microsystems might clash and not support women in computer science. Beth as a young teenager found the online gaming community provided her with an opportunity to play free computer games at a time when her "technophobe" parents would not buy them for her. She also felt entitled to enter this space because she had been encouraged to play with all toys whether they were coded as for girls or boys. However, the sexist behaviour of males online left her feeling unsafe (Michell et al., 2017).

Evidence of clashing rather than aligning microsystems also occurred in our current study. In one example, the heightened awareness of gender imbalance in computer science classes amongst some teachers and the desire to change this clashes with the apparent lack of experience of female students: "*Yes absolutely! Girls are not exposed to enough technology when they are young. They are unlikely to select to study [computer science] if they've never experienced success*" said one respondent. In another example, a participant noted that it is the parents' influence that clashes with the desire of teachers to increase the representation of females in computer science. Parents either want their offspring to study another "more academic" subject, or it is "*parents [who are] reluctant to use technology*" that deters girls from taking up digital technologies. The association of computer science has many negative associations with parents and communities, according to our respondents, who perceive it as an "entertainment" rather than vocational discipline. As one participant said:

"*Girls then tend to think IT is for boys and IT is about making games […] Parents themselves do little to challenge pre-existing gender beliefs*", while another notes: "*many parents see DT as getting in the way of their child's learning rather than supporting their learning - as a form of entertainment rather than something useful so students have formed this opinion too.*"

Clearly there is an opportunity here for intervention, that is, to challenge parental and wider community gender stereotypes and perceptions of the computer science industry. One way in which perceptions of computer science could change—and which illustrates the layering influence of the various social levels—would be to increase the value of a computer science degree program (exosystem) at the university entrance level and/or make it a compulsory subject in high school.

5.4. Microsystem

There are multiple microsystems which affect a young person, for example, the family, school and peer group, and workplace in adolescence. At the microsystem level are all the relationships that interact directly with the student (Basham et al., 2010, p. 15), it is effectively a system of interactions.

The reasons teachers identified for the lack of gender diversity are varied, but were concentrated at the microlevel of the classroom, while also reflecting macro level values of male domination. The key themes were male-dominated classroom culture (n = 29); stigma (n = 5); intimidation (n = 4) and lack of experience (n = 1). Most respondents who said there were gender diversity issues in their digital technologies classrooms indicated that there was a majority of male students. In some cases responses were specific, for example: "*90% boys*" or "*a ratio of 1 female [student] to 10 male [students]*". Others further suggested that it was the culture within a majority-male students classroom that discouraged girls who were "*Intimidated by boys and their technical lego building* *skills*", while another participant notes that "*boys dominate the class*" (Table 2).

Table 2
Reasons for the lack of gender diversity.

Key Themes	Mentions	Key Themes	Mentions
Male dominated classrooms	Total 29	Lack of Experience	Total 1
Stigma	Total 5	Intimidation	Total 4
● Stigma ("girls think it's a male subject")	3	● Female students are intimidated by topic	2
● Girls avoid the topic	1	● Boys dominate the class	1
● Peer pressure (girls drop out when their friends aren't in the class)	1	● Difficult for women teachers as well as female students	1

In response to a question about whether participants employed strategies to increase the engagement of female students in their classrooms, 47.59% of responses were in the affirmative. Key diversity strategies were to change the type of projects to cater to girls' interests, viz, collaboration, creativity, and real-world application (n = 13) and create specific programs for girls (n = 13). Amongst our participants there did not seem to be the awareness that both strategies are grounded in, and therefore likely to reinforce, stereotypical or traditional gender roles. Other strategies included directly inviting female students to participate in Robotics Club, creating an additional elective, promoting female students' work at assemblies and parent information nights, creating a Girls' Advisor position, changing assessment methods with an increased focus on planning and writing stages, highlighting the need for women in IT, and having female presenters visit the school, with one mention of each respectively. Most of these strategies have already been identified in the literature (see for example Goode, 2008), but what is missing from this list is the focus on creating a culturally relevant curriculum (Goode, 2008), and an understanding of stereotype threat and subtyping.

At the micro-level, then, we see the maintenance of macro-level values of male dominance, and even where strategies are being implemented to effect change, there is the risk of maintaining gendered stereotypes through the engagement activities being chosen.

6. Discussion

In this paper we have used the example of a national survey distributed electronically to secondary school teachers in 2017 to illustrate the need for research and interventions at multiple levels in the Australian community to solve the intransigent problem of gender inequity in the computer science industry. We have shown how the issue of male dominance in the computer science industry, and in most high school computer science classrooms surveyed, mirrors that at the macro or cultural level. Despite a national willingness (Turnbull, 2015, 2016) in recent years to invest in digital technologies and to encourage more girls and women into the field, when it came to diversity training and support in high schools, a majority of survey respondents reported they were inadequately trained to teach a diverse group of students, and those who invested in diversity strategies were unaware of the ways in which they were employing and perpetrating gender stereotypes (Betz & Sekaquaptewa, 2012; Patitsas et al., 2015, pp. 61–69). Moreover, those teachers who were wanting to encourage more girls into the computer science classroom faced the barrier of girls' disinclination either through lack of experience or parental discouragement.

One thing that our survey analysis suggests, therefore, is that without attention to the different levels identified by a socio-ecological analysis, efforts to solve the problems of diversity in digital technologies education are likely to founder and remain only marginally effective. There is an abundance of research literature, some of which we have cited in this paper, but there is little point in using this or government rhetoric devoted to diversity if teachers do not have the time, training or resources to focus on the issue in classroom and curriculum development. Conversely, provision of resources or curriculum will do little to shift the problem if family influences and societal gender assumptions continue to teach girls that computer science is not a career option for them. The teachers who responded to our survey were well placed to identify these problems, but currently their insights do not have a strong chance of influencing broader policy. If teachers are to improve perceptions of computer science at the local level, they require support in terms of material resources and sustainable workloads that cannot be provided through "awareness" efforts alone. At the same time, awareness and training do also remain crucial components of efforts towards change.

Such complexity demonstrates the importance of attending to social theory when trying to address such "wicked" problems (Rittel & Webber, 1973). All attempts at creating social change must be based on an explicit set of understandings about how social structures work and where they can be shifted. It is our proposition that an explicitly articulated socio-ecological analysis, or other similar multi-level analyses, provides the best basis through which to cover all the bases and thoroughly investigate both where and how the problem is reproduced, and which sites need intervention to prevent bottlenecks where change is held up. Achieving the enactment of such multi-dimensional approaches, of course, is the next problem, but at least such an analysis shows why nothing short of such effort is likely to be significantly effective.

There were limitations with our study. Our sample was small and 56% of respondents have a university accredited degree in Information Technology, Information and Communications Technology or Computer Science. A 2015 analysis showed that about 30% of computing/information technology teachers were teaching out-of-field (Weldon, 2015), meaning they have not studied the subject for at least one semester at second year tertiary level, or they have not trained in teaching methodology at tertiary level for the area. Therefore, there is a risk that the percentage of participants with a university specialist degree in our sample is not representative of Australian Digital Technologies teachers and our results need to be interpreted considering this aspect of the dataset.

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Appendix. Survey Questions

1 Do you teach in a state or independent school?
2 Is your school in an urban (metropolitan) or rural/remote (country) area?
3 Which state are you in?
4 Is your school a single sex or co-educational school?
5 Where is your school ranked on the government's Index of Community Socio-Educational Advantage (ICSEA)? – with explanations about the index.
6 How many different teachers teach digital technologies at your school?
7 How was the most recent decision made about who teaches digital technologies at your school (select all that apply)?
8 Is digital technologies study compulsory or elective? Please state whether compulsory/elective and at which year levels.
9 What is the gender make up of digital technologies teachers at your school?
10 Are students at your school involved in any extra-curricular computing or digital technology clubs, competitions, or activities? (Choose all that apply)
11 If you ticked yes above to 'outreach programs' or 'competitions', please give the names of the programs.
12 Approximately how many students study digital technologies (or computer science) in an elective at your school in any one year? [Year 7]
13 What computing facilities does your school offer for students? (select all that apply)
14 Are you and your students able to access online resources easily at your school?
15 What computing facilities are available within digital technologies classes at your school?
16 Do you feel these facilities are sufficient?
17 If resources are insufficient please state what resources you would like.
18 In your experience, what motivates students to study electives with digital technologies at your school?
19 In your experience, why aren't students motivated to study electives with digital technologies at your school?
20 At what levels do you teach digital technologies elective classes?
21 What specific digital technologies subjects do you teach? (please list all)
22 Over the last 5 years has the number of students studying digital technologies in an elective in a typical class taught by you increased, decreased, or stayed about the same?
23 Is this consistent across all elective digital technologies classes in your school?
24 Approximately how many students are in a typical class taught by you (that includes content on Digital Technologies)?
25 What kind of activities do students do in your Digital Technology class?
26 Do you have any industry visitors or CSIRO partners (e.g., Scientists-in-Schools, ICT-in-Schools) visit your class?
27 If yes, who arranges these visits?
28 If no, why not?
29 Do you see gender diversity issues in your classrooms? If so, please describe.
30 Do you see gender diversity issues in other subject areas not related to digital technologies? If so, please describe.
31 Approximately what proportion of students in your digital technologies elective classes are female?
32 What do you see as the reason for this proportion?
33 Over the last 5 years has the proportion of female students studying digital technologies in your elective classes increased, decreased, or stayed about the same?
34 In your experience what motivates female students in particular to study digital technologies at school?
35 In the past two years, have you employed any strategies in the classroom to increase engagement by female students? If so please describe.
36 Do you see gender diversity issues in other subject areas not related to digital technologies? If so, please describe.
37 In the past two years, have you employed any strategies in the classroom to increase engagement by low socio-economic status students? If so please describe.
38 In the past two years, have you employed any strategies in the classroom to increase engagement by Aboriginal and Torres Strait Islander students? If so please describe.
39 In the past two years, have you employed any strategies in the classroom to increase engagement by students with disabilities? If so please describe.
40 In the past two years, have you employed any strategies in the classroom to increase engagement by students from other racial, ethnic or cultural minority groups? If so please describe.
41 Have you ever had training in supporting diversity in the classroom? If so how? (choose all that apply)

42 Do you feel you have sufficient resources to support diversity?
43 What resources would you like to support diversity? (choose all that apply)
44 What do you feel are/would be the most useful resources in supporting diversity?
45 If you had the resources you want, how would you address diversity? Or if you do have the resources you want, how do you use them?
46 What do you think are the challenges specific to Digital Technologies as a discipline with respect to increasing diversity?
47 Do you think there are jobs and opportunities in digital technologies fields?
48 Do you feel that you have the resources that you need to point students towards a career in digital technologies?
49 Is there anything else you would like to add?
50 How many years of teaching experience do you have?
51 What is your main teaching specialisation?
52 Where did you get trained in the digital technologies field? (choose all that apply)
53 What gender do you identify as?
54 What is your age bracket?

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