SPOTLIGHT ON UNDERGRADUATE SCHOLARSHIP

Women and Computer Science

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Abstract

A plethora of jobs for information and communication technology professionals is predicted for the future, and female students outnumber male students in tertiary education. Nevertheless, women are significantly underrepresented in the computer science field. Stereotyping and lack of interest, encouragement, exposure, confidence, and role models are some of the factors contributing to this gender gap issue. However, most factors are actionable and these actions need to be taken to ensure the 21st century's advanced technological world does not miss out, for our society's benefit, on women's perspectives and innovative technological contributions.

In recent years, there has been increasing advocacy regarding the importance of computer science (CS) and coding in our society. Due to the prevalence of computers and their application in our daily lives, and also the high demand for Information Communication and Technology (ICT) professionals – over 180,000 by 2019 in Canada (ICTC, 2016) and 1.4 million by 2020 in the U.S.A. (https://girlswhocode.com/) – more people, children included, have been encouraged to get involved in the CS field. At the same time, another current movement is shedding light on a deeper issue: the CS field is male dominated. The Women in Computer Science movement advocates the importance of closing the gender gap in technology. Examples of organizations helping in this direction are https://girlswhocode.com, http://ladieslearningcode.com/, http://sheplusplus.org/, http://code.likeagirl.io/, and http://railsgirls.com/.

Female university participation has increased significantly, even in areas previously dominated by man, such as law and medicine. However, they still remain underrepresented in science, technology, engineering, and mathematical (STEM) degrees (Hango, 2013). Even among the STEM graduates in Canada, Statistics Canada found that women accounted for about 30% of the mathematics and computer science graduates (Hango, 2013). In 2010, in the age group of 25 to 34 years, two-thirds of young women versus half of young men had attained a tertiary degree (OECD, 2012). By 2025, providing that the same trend continues, there will be a ratio of two to one, female to male students, in tertiary education in Canada (OECD, 2012). However, this is not occurring in the technology field despite the anticipated plethora of jobs in the future. These trends are not occurring just in Canada; the National Science Board's "Science and Engineering Indicators for 2012" are reporting similar women representation numbers for the US (Google, 2014). OECD (2015a) reported that in 2012 only 20% of CS graduates were female, a decrease from 23% in 2000. CS is the only subject area decreasing in female participation since then.

At the high school level, according to the College Board (2016), 13,506 (23.3%) female students compared to 44,431 (76.7%) male students took the Advanced Placement (AP) Computer Science exam in 2016. This participation rate is significantly low, especially when the overall participation rate for all AP courses (56.3% female versus 43.7% male) is considered. Although the percentage of female students taking the AP computer science exam is increasing (18.7% in 2013 to 23.3% in 2016), there is still a long way to fully close the gender gap. Locally, at Brandon University, through the years 2011-2016 only three female students graduated with a major in computer science, representing 10.7% of all computer science graduates. Over the same years, no females graduated with a minor in computer science (Brandon University, 2017).

Clearly, women are significantly underrepresented in the CS field (Diekman, Brown, Johnston, & Clark, 2010). But why does this really matter? Women's underrepresentation has implications in many areas. First is the labour supply shortage problem (Google, 2014), which is exacerbated with the lack of female participation. By disproportionately excluding women from the CS workforce in a time where "the overall need for computing professionals has severely outstripped the number of graduates entering the workforce" (Wang, Hong, Ravitz, & Ivory, 2015, p. 1), the result is that a significant number of CS professional positions in many fields will remain unfilled. Additionally, jobs in CS provide, on average, better labour market outcomes (Saujani, 2015), labour market conditions (Hango, 2013), lucrative and high-status careers (Master, Cheryan, & Meltzoff, 2016), and pay equity since there is no gender pay-gap among CS engineers (Saujani, 2015).

Labour outcome is not the only factor. Technology sparks innovation (Saujani, 2015), and women's underrepresentation in technology means the perspectives of women that could lead to better innovations are missed (Blankenship, 2015). Therefore, the field of CS "might not be generating the technological innovations that align with the needs of society's demographics" (Google & Gallup, 2016, p. 4). Having workforce diversity in the tech field will result in creating better products for diverse users (Google, 2014). In the opposite scenario, the female talent pool is under-utilized (OECD, 2012) in contributing to technological innovations for the greater good of the society. By implication, this can potentially result in talent loss. Workforce diversity "contributes to a richer mix of ideas, inventions, innovations, and problem solutions" (Hill & Rogers, 2012, p. 23;). OECD (2015a) highlighted recent research findings that "gender diverse business teams have greater success in terms of sales and profits than male dominated teams" and "having more women on a team contributes to better problem solving" (p. 9).

Despite the emphasis on diversity and innovation, as well as the promising number of future job opportunities for people with CS skills, women do not seem to buy into this trend. Female high school students are less interested in learning CS than male students (Google & Gallup, 2016). Additionally, women are significantly less likely than men to earn a degree in CS. Similar findings are shared in the Hango (2013) report: Women are less likely to choose a STEM education, regardless of mathematical ability and especially in the field of engineering, mathematics and computer science. Even young women with high level of mathematical ability are significantly less likely to pursue STEM studies, when compared to their male peers, even when compared to young men with a lower level of mathematical ability (Hango, 2013). Moreover, OECD (2015a) reported that "women who graduate in STEM subjects are significantly less likely than men to pursue a career in those fields," with a percent of 43% versus 71% for their male peers (p. 8). The question remains: Why? Is it due to women's choice and lack of interest for the field or are there other underlying factors?

Encouragement and exposure were identified by Wang et al. (2015) as leading factors influencing women's pursuit of CS and related fields; in particular, family plays a critical role. Female students are less likely than male students to be told by a parent (27% vs 46%) or a teacher (26% vs 39%) that they would be good in CS (Google & Gallup, 2016). Stereotypes may also influence parents and teachers, and cause unconscious bias toward female students (Google & Gallup, 2016). Master et al. (2015) concluded, "By the time they are adolescents, girls are aware of the negative stereotypes about their ability in math and science . . . They also know that STEM fields are dominated by males" (p. 12). The Programme for International Student Assessment (PISA) found that parents of 15-year-old boys and girls with the same level in mathematics are more likely to believe their sons, rather their daughters, will follow a career in the STEM fields (OECDb, 2015).

Klawe (2013) explained how computers became a "boys" thing almost overnight. In the 80s, she noted, when personal computers entered homes and schools, they were mainly used by children to play games. Those computers, however, had very low computational power and graphics capabilities, and almost all games were either ping-pong style or involved shooting items or persons. These games were not appealing to young women who gradually disengaged.

On the other hand, young men were learning how to program the computers to create more of those games. This early exposure and frequent computer usage relates to the current interest in computer science. Female and male students may have similar exposure to computers at school and at home, but they tend to use computers for different purposes. Male students might use computers mainly for playing games, which exposes them more to the idea of creating. They are also more likely to join computer clubs and to consider computers a very important part of their lives (Ogan, 2004). Female students, on the other hand, are less likely to share the same excitement. They tend to see computers as a tool or use them mainly as a social device, which is considered a passive consumption form of computer usage (Alexander & Carey, 2009).

Hence, female students come to a CS course with less exposure and experience in computers than their male peers, and with less confidence in their ability to complete the course (Ogan, 2004). "Along with student interest, confidence in their ability to learn computer science may influence who pursues it" (Google & Gallup, 2016, p. 15). Fewer than half of female students feel very confident they can learn computer science, compared to two-thirds of male students: "Students who are very confident they could learn CS are three times more likely to be very interesting in learning CS" (p. 16). Female students can be intimidated by their male peers and lose confidence in their abilities when entering a CS course; "the only people at the end are the people who have been in computer camp since they were five" (Kaufman, 2013, para.10).

Female students do not feel confident enough to try CS, and they feel that they do not belong in a computer science course (Blankenship, 2015). Master et al. (2015) added that female students' lower sense of belonging in a CS class could be attributed to their not fitting in with CS stereotypes. A welcoming educational environment plays an important role. The Master et al. (2015) research findings show that "providing [female students] with an educational environment that does not fit current CS stereotypes increases their interest in CS courses and could provide grounds for interventions to help reduce gender disparities in CS enrollment" (p. 1). Examples of stereotypes in classrooms are science fiction posters, stray electronic parts, video game posters, and an overall feeling of "geek" room or Boy's club, which make the educational environment unappealing to women (Klawe, 2013).

The computer science stereotypes are present not only inside the educational environment but also in the broader society. Cheryan, Master, and Meltzoff (2015) provided a very good summary of what these computer scientist stereotypes can look like: they are often "geeky" guys, socially awkward with technology being the main part of their lives; they play video games; they must be brilliant or genius; they have particular physical traits such as glasses or pale skin; they work in isolation (pp. 3-5). Similarly, popular movies and television shows (e.g. *Silicon Valley, The Big Bang Theory*) portray computer scientists as all male, obsessed with technology and "geeky." Only 7% of computer science characters in films or TV are women (Blankenship, 2015). Cheryan et al. (2015) argued that these stereotypes "act as educational gatekeepers, constraining who enters these fields" (p. 2). In this technological world, the inventors of Google and Facebook are all male and very few women are represented at the highest levels, for example, the Fields Medal or Nobel Prizes (Hill & Rogers, 2012, pp. 21, 23). Saujuni (2015) described it as follows: "Women cannot be what they cannot see." Having female role models in CS and sharing the stories of successful female computer scientists can enable young women to visualize themselves as computer scientists and can help to attract more women into the field (Cheryan et al., 2015).

Women need to see a meaningful value in the STEM careers, because just having positive female role models will not necessarily attract more women to the STEM fields. "If women perceive STEM as antithetical to highly valued goals, it is not surprising that even women talented in these areas might choose alternative career paths" (Diekman, Brown, Johnston, & Clark, 2010, p. 1056). Women prefer working with people over things, and this preference affects their choices of career paths. Individuals in STEM careers are often perceived as working in isolation, or with technology and machinery, which is perceived as a misalignment with fulfilling communal goals (e.g., working in collaboration and helping other people). “Women tend to endorse communal goals more than men” (Diekman et al., 2010, p. 1052), and these perceptions may influence women’s decisions to pursue a career in STEM. In computer science, for example, women may have difficulty visualizing the broader CS applications and the good they contribute to our society (e.g., medical breakthroughs). An incomplete or wrong perception about the STEM field can discourage women from entering it (Wang et al., 2015). Diekman et al. (2010) argued that interventions to increase awareness could deal with misconceptions and could result in more women considering careers in those fields.

Lastly, Hill and Rogers (2012) provided an alternative rationale to assist in understanding some of the reasons for women’s underrepresentation in CS and related fields: The Creativity Factor. They argued that since high-performance mathematics (important in all STEM fields) require “highly creative thinking” (p. 21), the gender difference in creative achievement should be examined in order to understand the gender gap in those fields. Creative achievement is seen to be enhanced by factors such as play, curiosity, and the willingness to take risks and to accept failure and rejection. Men are viewed as doing better in those areas because they tend to be more playful (play has been recognized as an important catalyst for the creative mind), risk-takers, and better able to accept rejection. Hill and Rogers (2012) wondered, is this difference in creative achievement among women and man due to nature or nurture? Saujani (TED, 2016) believed it is the latter:

> Most girls are taught to avoid risk and failure. We're taught to smile pretty, play it safe, get all A's. Boys, on the other hand, are taught to play rough, swing high, crawl to the top of the monkey bars and then just jump off headfirst. And by the time they're adults . . . they're habituated to take risk after risk. (2:20)

Many factors contribute to women’s underrepresentation in the CS and related fields, but acknowledging them is a start. What can be done, though? How can we encourage more women to get involved in the field? Klawe (2013) shared the Harvey Mudd College success story: how the college managed to increase the number of women majoring in computer science from 10% to 42% in five years. First, the college made it mandatory for all students to take a CS course in their first semester. The introductory course title changed from “Learning to program in Java” to “Creative problem solving in science and engineering through computational approaches using Python.” This made the course more appealing and approachable to women, who liked the idea of taking a course on creative problem solving. Second, the CS faculty (it is worth noting that 42% of faculty were female) worked to eliminate students’ macho behaviour, whereby a few more experienced students (usually male) intimidated the students with no prior coding experience. The students were put into groups based on their prior knowledge of computer science, and the emphasis was placed on team work, making the problems more fun, creating real-world connections, and providing a variety of options on assignments.

In addition, every year, the school organizes a trip to The Grace Hopper Celebration of Women in Computing, which is the world's largest gathering of women technologists (http://ghc.anitaborg.org/). Female students are given the opportunity to hear and meet in person some of the most successful women in the technology field. Partnership with the tech industry creates opportunities for the students to work in tech companies through summer internships. The implementation of the above changes resulted in a very popular CS introductory course, more graduates with majors in CS, and more non-major graduates taking higher level CS courses. A similar package of changes had a similar effect in the case of the School of Computer Science at Carnegie Mellon University (Ogan, 2004).

Blankenship’s (2015) identified six action points for high school teachers to encourage more female students to take CS: recognize the tech gender gap problem and encourage discussions; create safe, welcoming classroom environments (young female students are three times more likely to take a CS class if it is in a non-geek room); connect assignments to students’ interests and to the real world (e.g., cross-curriculum, computing for poetry and art, simulation of the spread of viruses); practise inclusive pedagogical practices such as peer instruction and group work; and lastly value all levels of skills in class, ensure that no student dominates in class, and focus on constantly encourage the students when they are struggling.

There is no question that women are underrepresented in the CS and related fields, and this tech gender gap becomes more significant when compared to the gender gap in other formerly male-dominated fields of study (e.g., law and medicine). My anecdotal evidence obtained through informal discussions with Manitoba CS educators (Crocus Plains High School, Vincent Massey High School, Hapnot Collegiate, and Brandon University) confirm this trend: There are a few girls taking CS courses, and this number decreases in the more advanced levels of CS courses. What is worth highlighting, though, is that in all of my discussions a common theme emerged: "We might not get many female students, but the ones we get are normally the top students in class," as one educator put it.

Many studies have tried to answer the question of why this gender gap issue exists in CS and STEM-related fields. Despite the lack of consensus on the reasons causing the gender gap, it can be agreed that the answer is rather complicated and depends on many factors. These factors span from women's personal interests and perceptions of the CS field, to deeper social and cultural factors and gender stereotyping. "Factors most related to female participation in CS though are actionable" (Google, 2014, p. 3), and this is the positive message coming out of this story. There are best practice examples that have dealt with the issue successfully (e.g., Harvey Mudd College, Carnegie Mellon University), and the first step toward a solution is to acknowledge the issue and to care enough to enact the solution. Taking into account the promising technological advances of the 21st century and the innovation they are going to spark, we ought to ensure that women are not left behind but become active participants of this innovation. This is not only due to addressing the gender parity issue and future labour shortages, but most significantly because allowing women's talent and female perspectives to be part of this innovation will result in better outcomes for our 21st century society.

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