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Where Are All the Women?: Exploring the Research on the Under-Representation of Women in Computer Science

Xiu Tian
tian12b@uwindsor.ca

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By

Xiu Tian

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By

Xiu Tian

APPROVED BY:

G. Salanitri

Faculty of Education

C. Greig, Advisor

Faculty of Education

June 10, 2020

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ABSTRACT

Women's participation in computer science is important for many reasons, including playing a significant role in a country's economic development. A skilled workforce is needed to remain competitive in the globalized world, especially in the area of computer science. This research aims to explore the recent research literature around the factors that contribute to women's low participation in computer science. Key to this exploration is helping to answer the question: Why does the proportion of women in Western countries' computing fields remain low, despite years of research and programs with the intention of increasing women's participation in computing? In order to address this question, and employing a feminist theoretical lens, I conducted a comprehensive literature review. To some degree, I also analyzed my own autobiographical experiences in the field of computer science to better understand how gender relations shape that world. The current study concludes that the main factors that shape women's low participation in computer science are gender stereotypes, a misunderstanding of science computer curriculum, "know-it-alls" learning environment, unfair work environment, and pay gap. All of these factors will be discussed using three explanatory lenses: psychological explanations, social factors and structural factors. In the end, I conclude with suggestions for how to increase the number of women within this field.

Keywords: gender, STEM, post-baccalaureate coding boot camp, leaky pipeline.

DEDICATION

To my Family
To my supervisor
and to all people who supported me

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Introduction

In this paper, I explore gender issues in science, technology, engineering, and mathematics (STEM) education. I'm interested in exploring this topic due to my gendered educational experiences in a post-baccalaureate coding boot camp. For me, my gendered experiences in coding boot camp illustrate to some degree why women's participation computer science is low relative to other areas of STEM. In my own experience, I was faced with gender stereotypes; gender stereotypes that often made me feel like an outsider, made me feel like I didn't quite belong. To put it a little differently, the social and historical gender stereotype of the computer scientist as objective and rational, reflects normative constructions of masculinity, but runs counter to stereotypes and prescribed norms for femininity. As such, many women like myself are likely not able to see themselves as computer scientists. My experience is not unique and may go to explaining why women tend not to gravitate to the computer science field. The data indicates in comparison with enrollment in engineering, science, and mathematics, women have an extremely low share of participation in computer science (Szelényi, Denson & Inkelas, 2013). Anna and Andriana (2015) conclude that studies within this field not only report insignificant improvement in the proportion of women in Western countries' computing fields but also alert us of a declining trend. What's more, that decline has been accompanied by years of research and affirmative action programs which are meant to increase women's participation in computing. Therefore, taking all the above into consideration, in this paper, I will contextualize the gender issues around women's low participation in computer science field.

Computer science is often discussed together with STEM when talking about gender issues, despite having the lowest share of women's participation. For example, in 2011 women between the ages of 25 to 34 comprised less than 40% of university graduates within STEM fields

(Hango, 2015), and in the field of computer science, they made up a meager 18% of graduates (Seibel & Veilleux, 2019). According to Catalyst, in 2016, Canadian women made up 27% of all recipients of STEM bachelor's degrees. Among these women who choose to pursue a degree in STEM, most do so in biology or science programs, resulting in even fewer women in computer science programs. These choices have consequences for women because computer science programs lead, on average, to better outcomes in the labour market in terms of employment, job match, and earnings. As there is an increasing need for more highly skilled people in the IT market, low participation of women in computer science causes women to miss out on attractive job opportunities and simultaneously causes the IT field to miss out on the broader range of perspectives and talents that women offer. So, to recap, the research has demonstrated that despite the increase in female enrollment in STEM fields (Hango, 2015), the number of women enrolling in computer science remains startlingly low. Situation varies according to location and culture. In the North American context, access to education may be relatively equitable for boys and girls. Nevertheless, even in such an equitable educational environment, there are still gender issues in education particularly in the computer science subject (Dyer & Susan, 2001).

Why wouldn't women go into computer science as a career? In order to encourage women's participation in computer science programs, it is important to figure out some of the benefits that are available to women. According to the American Association of University Women (n. d.), computer science has one of the smallest pay gaps between male and female professionals, with women earning 94% of what men earn (Computer Science.org, n. d.). This is no small matter, because equitable earning power can enhance the satisfaction women feel in their work. Moreover, the IT industry increasingly is generally perceived as a male domain, like mathematics, science, electronics, and machinery (Liisa, Nielsen & Trauth, 2001). This is a problem and a barrier for many women (Julie & Bogg, 2013). But this is less true of the computer science industry. This is not to say that the field of computer science does not have gender issues, because it surely does, but in some ways computer science companies are at the forefront of progressive workplace policies (Lau, Wong, Chan & Law, 2001). First, compared to other companies they tend have better work and life balance, and for women who also want to help raise a family this would be an important benefit. Of course, the notion that women are interested in raising a family in relation to their commitment to work, is also a way that labour market is gendered. How many men for example, take this into careful consideration when looking at whether or not to except a job? Computer science companies also tend to have more flexible working conditions. For example, in a report by the New York City Economic Development Corporation (n. d.), researchers found that many tech companies support videoconferencing and working from home. This may be an advantage for some women who are mothers, although, again, if this is the case, it also reinforces gender stereotypes in relation to childcare as a woman's issue. Furthermore, many of these companies offer flexible hours, allowing employees to work around their personal schedules to complete projects (Julia, 2011). For example, employers have introduced flexible working packages in order to attract, recruit, and retain highly qualified staff to their organizations. Work flexibility refers not only to variation in time and place of the job, but also sharing of the job, career breaks, part-time and term-time working (Shagvaliyeva & Yazdanifard, 2014). Possenried and Plantenga (2011) discussed three broad categories of FWA-flexi-time (flexibility in scheduling), work from home (flexibility in location), and part-time (flexibility in length of the work). They are frequently combined to complement each other. But that is not all. Computer science companies also tend to have generous maternity leave and childcare policies. For example, Facebook offers employees six weeks of paid leave to care for sick children and family members as well as four months of paid maternity leave (Collins, 2015). Apple offers 18 weeks of paid maternity leave and nine weeks of unpaid maternity leave, which is higher than the industry average, which is 11 weeks of paid maternity leave and nine weeks of unpaid maternity leave (Connley,2017).

Above, I have highlighted some of the advantages available to women who enter the field of computer science. Now, I briefly highlight some of the background reasons that shape women's experiences in relation to computer science.

For many women, multiple factors help move women successfully into the field of computer science. Hango (2015) discovered that factors such as self-efficacy in relation to mathematics, prior coding experience, learning and working environment, work and life balance, and pay gap all are important to consider if we want women to succeed in computer science. For example, Palma (2001) and Sanstad (2018) both researched the 'fear of science' in women. Some women have a fear of science -too-difficult- which resulted in women being reluctant to participate in computer science. This fear of computer science is due to a low mathematical self-efficacy in women and a belief that the computer science field is math intensive. However, for women who choose the computer science field, their prior coding experience shapes their academic interest in computer science and less influenced by the lack of mathematics self-efficacy as they have been exposed to the computer science context. But that is not all, the learning environment such as 'know-it-all' and male dominant working environment scare women away from the computer science field even after they enter into this field (Weisul, 2017). In terms of work and life balance, this can be a barrier for women, as women are regarded as main caregivers in many families. What's worse, although the gender pay gap is smaller in the computer field than that in other STEM areas, it still drives some women away even after they have overcome all above problems as they are paid less than their male peers when they are on the same level.

Personally speaking, based on my own experience, incombination with the current research situation on women's low participation in computer science field and the outcome, this study is conducted. Helping more women enter into this field is beneficial not only to individuals but also to society. It is a truism well-grounded in research that educating girls, and employing women are key to a society's well-being (Hill & King,1995). Multiple factors which contribute to women's underrepresentation in computer science are low self-efficacy in mathematics, prior coding experience, work and life balance and pay gap. In this study, these key factors in mainstream research are discussed. Next, in order to help the reader better navigate the contents of the paper, I provide some key definitions.

Key Definitions

Gender Stereotype: Sexualized Gender Stereotypes (SGS) are stereotypes that portray women and girls as sexual objects who should singularly prioritize their sexualized attractiveness and portray men and boys as sexually voracious actors who should only value a girl as a sexual object rather than a person (Brown & Stone, 2016) Consistent with the emphasis of SGS on girls' sexualized attractiveness as a singular priority, both boys and girls perceive girls' sexualized attractiveness to be incompatible with other traits, including intelligence and competence (Starr & Ferguson, 2012; Stone, Brown, & Jewell, 2015). These sorts of stereotypes are harmful; they can restrict individual expression and creativity, as well as hinder personal and professional growth. Socializing agents including parents, teachers, peers, religious leaders, and the media pass on gender stereotypes from one generation to the next.

Science, Technology, Engineering, Mathematics (STEM): What is STEM? According to Ferguson and Zhao (n. d.), STEM fields of study include 'science and technology, engineering and engineering technology' and 'mathematics and computer sciences' (STEM). In this research, we will refer to STEM based on this definition.

Coding Boot Camps: Stroud (n. d.) described that coding boot camps, are structured and intensive educational programs designed to help students gain key programming and technical problem-solving skills through short but highly-focused instructional sessions. Coding boot camps (also frequently referred to as IT boot camps) were launched as a way for prospective employees to gain the needed skills for new jobs or career advancement without having to spend the time (4 years or longer) and money (often a hundred thousand dollars or more) required to obtain a college degree in computer science or a similar major.

Leaky Pipeline Metaphor: According to a commonly used metaphor, a girl should be entering the ‘pipeline’ of computing when she enters school, by taking preparatory courses, becoming experienced in the use of computers and thus becoming prepared for the undergraduate college degrees in computer science. Further along the ‘pipeline,’ –from school to the labour force- and depending on the educational system - a young woman would major in computer science and after that, she would graduate from a computing discipline. At the end of the educational pipeline-with a bachelor’s, master’s or doctoral degree in computing-this woman would enter the workforce, advancing from entry-level positions to more senior positions in the computing field (Bartol & Aspray, 2006b). However, we know from research that many women do not follow this pipeline from beginning to end, although many women begin. Why do women ‘drip’ or ‘leak’ out of the ‘pipeline’? ‘The term ‘leaky’, then, refers to the way in which women leave or are nudged out of STEM occupations in metaphorical drips, ‘leaking’ out of their chosen field.

In order to best address these questions, I employ a feminist theoretical framework to help explore and understand the complicated relationship between gender, gender relations, and computer science. It is this framework that I turn to now.

Theoretical Framework

In this paper, I adopt a feminist theoretical framework. Feminism is a theoretical orientation that provides ideas and insights aimed at defining, establishing, and defending equal political, economic, and social rights for women in education and employment (Arnot & Dillabough, 1999). Femininity can be viewed as a socially and historically constructed condition which subordinate women within a patriarchal culture. Second, women cannot achieve equality on foundations set by men. Instead, what is required is a process of building a more adequate social theory through utilizing studies on women, by women, in order that their perspectives and experiences are recovered from the realms of marginality. This approach does not seek to replace a masculine truth with the equal 'bias' of a feminine truth. Instead, it is argued that differences and diversities amongst women mean that there cannot be one essential category of woman, but multiple experiences, identities and truths. This is the perspective of postmodern feminisms (Powell, 2013). Hekman (1990) noted earlier that a postmodern feminism would reject the masculinist bias of rational-ism but would not replace it with a feminist bias. Rather it would take the position that there is not one (masculine) truth but, rather, many truths, none of which is privileged along gender lines. This study is based largely on the third approach.

I chose feminism as my theoretical framework because it explains how gender relations work in our culture to often privilege men as a group over women as a group. Feminism places gender central in the analysis, and as such, helps women and girls make sense of their experiences as a group, moving their critical scrutiny away from individual explanations, to focus on the broader structural issues.

In the literature review, I analyze what this theory offers researchers, how it helps us to see the world through a gendered lens, and why it makes sense to use this theory in the research process. In this way, I strive to be transparently subjective. In the data collection and analysis, feminist theory also provides a framework and foundation. And while I primarily draw on feminist theory, I also draw, to a limited extent, on anti-oppression theory (Barnoff & Moffatt, 2007). It is this theory that I briefly turn to next.

Briefly, anti-oppression theory helps to explain how power relations work in a society to privilege some groups over others. Although I'm very interested in gender relations, anti-oppression theory helps us better understand phenomena like anti-Black racism. The recent high-profile examples coming from the United States such as the case of 'Ms. Cooper,' and the horrific case of 'George Flood,' requested us to ask how race and racism function both at the institutional level but also at the individual level. In any event, my paper is also based on the theory of "anti-oppression." As Clifford and Burke (2005) claim,

> there is a need for a critical (and self-critical) anti-oppressive social work ethical framework which can bring together traditional ethical issues and anti-oppressive social work values drawing on long-standing concepts of social justice, anti-racism, and classical feminism, as well as more contemporary perspectives based on critical and feminist interpretations of 'affirmative' postmodernism. It specifically includes relationships of power within social services organizations, and power relationships between service users and social workers. Our view of oppression also specifically includes the social construction and complexity of notions of power and social division, and is aware of the dangers of both foundational

> certainty and postmodern uncertainty. There are some basic principles as a framework for assessing any discourse or behaviour. They are inter-related and have to be read together rather than as separate principles. Anti-oppressive principles are social difference, reflexivity, the historical dimension, interacting social systems and power. Anti-oppression theory is important because it provides a framework for understanding the world and our own position in it, questioning and challenging our practices, and creating new approaches that counter oppression and lead toward reconciliation and decolonization. (Clifford & Burke, 2005).

Anti-oppression theory, as Clifford and Burke (2005) suggests, is interested in how power works in a society to privilege some groups over others. This theoretical orientation scrutinizes, for example, how race and racism structure society to stratify groups of people along race-based lines. With the end result of some racial groups earning unearned benefits over others. One only has to glance at the recent events in the United States, in particular the protest across various American cities including Minneapolis, to see the truth of this statement (Feagin & Elias, 2013). Anti-oppression theory of course is also interested in questions of gender. It makes the assumption that we live in a patriarchal world where men as a group hold power over women as a group. To adopt this theoretical orientation also suggests that we find a way to address these structural and individual inequities to make the world a better place. In the section above, I have briefly sketched out my theoretical framework. Now I turn to the literature review.

Literature Review

Dating back to the 19th century, women were involved in computing. Probably to the surprise of many readers, women were the first software engineers. Ates (2017), for example, demonstrated that in 1843, Ada Lovelace, who was an English mathematician and writer, became the first computer programmer by designing the first computer algorithm. Lovelace went on to explain how it would work on Babbage's proposed (but non-existent) Analytical Engine (Ates, 2017). Although Lovelace's example is well over 100 years old, more recent history has also demonstrated women's participation in computer science. During the post-World War II era and well into the 1960s, software engineering was considered "women's work" (Eveleth, 2013). Men tended to do other work such as hardware. The popular American magazine *Cosmopolitan* famously ran a 1967 issue about "The Computer Girls." In the article, American Admiral Hopper stated that women are "naturals" at computer programming (Ateş, 2017). Oddly, it would be a rare thing to hear an authority figure today say something similar about women and computing. In any event, in the1980s, women's participation in computer science experienced a great decline. According to Ateş (2017), the reason is that "(some) men didn't want women enjoying all the benefits." Then marketing campaigns, aptitude tests that seemed to favour men, ran alongside advertising and popular films such as *War Games* (1983) and *Weird Science* (1985) that masculinized technology within popular culture. At the same time, video game consoles became primarily marketed to boys. Taken together, the cultural message was clear: 'computer science is for boys, not girls.'

Other powerful changes were happening during the 1980s that linked technology with masculinity. Seibel and Veilleux (2019) wrote in their research that in 1984 a gender shift in computing began permeating college campuses. This shift they argued resulted in a sharp decline of female CS graduates by 1987. One hypothesis for this shift was the notion that as personal computers became available for public consumption, companies marketed them mainly to men and boys (Seibel & Veilleux, 2019). Within the context of North America, home computers at this point in time, became 'toys for boys.' There were a number of gender consequences for this convergence. One is that boys, at a young age, were exposed to, and gained experience at an 'entry level' in computing, more than girls. Second, this convergence also helped to solidify 'computing' and 'coding' as a form of technology and then linked it to masculinity. The linkage between this type of technology and masculinity has only strengthened overtime, being fused together like the linkages from the past that saw militarized and motorized technologies connected to masculinity. In many ways technology as expressed through computing and computer science has become a symbol of a socially sanctioned masculinity. Just think of the hugely popular super hero *Iron Man*, or think of the very real-life computer 'super hero' Elon Musk and his Space X adventures to see the truth of this statement,

Next, I will focus on the existing factors that still keep women out of the computer science field despite the measures to encourage women's participation in computer science programs. Therefore, this is a study aiming at "fixing the women" (Wyer & Adam, n.d.), which refers to women who have been immersed in gender stereotypes. Stoilescu and McDougall (2011) explored differences between female and male students in undergraduate computer science programs in a mid-size university in Ontario based on Kelly's (2008) three levels of digital divide -resources, instruction, and culture specific knowledge. On the same topic within a broader field, Hango (2015) examined whether mathematical ability in high school is related to gender differences in STEM university programs. Hango (2015) discusses factors such as differences in labour market expectations including family and work balance, and differences in motivation and interest. Hango (2015) found that men aged 25 to 34 with STEM degrees had lower unemployment rates, higher wages and a lower rate of job mismatch than their non-STEM counterparts. The labour market outcomes of women with STEM degrees did not clearly differ from non-STEM women in this age group. This indicates that different labour market outcomes can be another factor contributing to women's low participation in computer science programs, especially when there is an assumption that computer science can be difficult for women to learn and to pursue as a career.

Hango (2015) also reports that students who chose a STEM university program had higher Programme for International Student Assessment (PISA) mathematics scores at age 15, higher mathematics marks in high school, and had a more positive perception of their mathematical ability than those who opted for other fields of study. Hango's conclusion was that mathematical ability in high school is related to gender differences in STEM university programs. However, while it is true that students who chose a STEM university program had a higher mark in high school, we cannot inversely make an inference that students who have higher marks in high school will probably choose STEM university programs. This does not make sense in a logical way because even women with high mathematical ability will be less likely to choose STEM program when compared with men with lower math scores. Therefore, mathematics scores and self-efficacy in math should not be a critical reason resulting in women's low participation in computer science programs. For example, in Hango's research, among those who went to university, 23% of women in the three highest categories of PISA scores (out of six) chose a STEM program, compared with 39% of men in the three lowest categories of PISA scores. This suggests that regardless of mathematical ability, women will be less likely to attend computer science programs because of their assumption that computer science is difficult for women.

In recent years, colleges, universities, and other institutions have been making an effort to encourage women to enter technical fields, as well as finding ways for women to build their self-confidence as computer scientists (Kossuth,2004). To increase women's participation in computer sciences, colleges try to appeal to a broader range of students by adopting different approaches to the field itself or "fixing the curriculum." Among all of these efforts, the most outstanding one is the success of BRAID colleges in increasing the number of women CS majors (Weisul, 2017). As anitab.org (“BRAID”, n. d.) demonstrates,

> since 2014, 15 CS departments (“BRAID Schools”) have committed to implementing a combination of four commitments in efforts to increase the participation of students from underrepresented groups — racial/ethnic minorities and women — in their undergraduate CS programs. BRAID colleges act to address a minimum of three of the following commitments: Modify introductory CS courses to make them more appealing and less intimidating to underrepresented students. Lead outreach programs for high school teachers and students to build a diverse pipeline of students. Build confidence and community among underrepresented students. Develop and/or promote joint majors in areas like CS and biology that are attractive to underrepresented students.

What is most interesting about the program described above, is that it is not only a program that works toward securing more women in sciences, but focuses on minority women. This is important as not all women have the same opportunity to develop their mathematical confidence and abilities. Women of colour, young girls from working poor and working-class backgrounds are less likely to do well academically in school, and by extension less likely to enter STEM programs. So, an educational program that attempts to address the inequities recognizes how gender overlaps with other social categories such as social class race to shape the career trajectories of women and girls.

In recent years, women’s underrepresentation in STEM fields has garnered widespread attention in public, academic, and policy circles. For example, President Obama, back in 2015 indicated his commitment to addressing the lack of women in STEM fields through his White

House Educate to Innovate Program, and he targeted efforts to the field of computer science as part of the Computer Science for All Initiative (Sax et al., 2016). As bamawhitehouse.archives.gov ("STEM for all", 2015) shows,

> [I]n order to meet the projected work-force need of 1 million additional STEM graduates by 2022, and to realize the vision of a highly diverse, creative, and sufficient STEM workforce and a STEM-literate citizenry, the Nation must engage all students. This effort must include women and minorities who are poorly represented in many STEM fields. The President's 2017 Budget includes a Computer Science for All plan that builds on the momentum at the state and local level to give every P-12 student the opportunity to learn computer science. The Budget invests $4 billion in mandatory funding at ED, available over three years, to support the ability of all 50 states to expand access for all students to hands-on computer science instruction and programs of study. In addition to state-level grants, the 2017 Budget dedicates $100 million in competitive grants specifically for leading districts to execute ambitious computer science-expansion efforts for all students—with a focus on reaching traditionally underrepresented students—and to serve as models for national replication.

Even with high profile policies such as the above, alongside the development of third wave feminism and the high demand of the job market, there is still a low rate of women's participation in computer science. Catalyst (2016), for example, found that Canadian women made up a meager 27% of all recipients of STEM bachelor's degrees and under a quarter (22.3%) of computer and information systems professionals. Moreover, they were less likely to pursue higher-paid fields, such as computer science. Despite some small gains made by some women in some fields like medicine and law, helping women succeed in computer science remains a challenge.

Some scholars have researched factors that contribute to women's low participation in computer science. Hango (2015), and Seibel and Veilleux (2019), for example, discuss factors such as self-efficacy of mathematics, prior coding experience, learning and working environment, work and life balance, and pay gap. What these researchers found, not surprisingly, was that almost all factors are defined by gender stereotypes. For example, self-efficacy in mathematics is shaped by the stereotype that boys are 'naturally' better in math than girls. The false belief that boys are naturally better at math than girls, automatically places girls at a disadvantage in schools. Girls come to believe that they might as well choose another subject area to become experts in, given that they are not likely to shine as bright as the boys in math class. But there are more stereotypes than this, that need to be challenged to help women think more closely about entering computer science. This includes scrutinizing the way in which women are expected to do most of the domestic labour constituting what sociologists call the 'double shift,' and if they have children, are expected to sacrifice their career to stay at home.

Drawing on patriarchal understandings of gender, work and life balance is from the stereotype that women should stay in the home to nurture children and do housework while men are financial providers for families. Master, Cheryan, and Meltzoff (2016) discovered in their study that stereotypes are a powerful force driving girls away from computer science. Even though stereotypes are often inaccurate, children absorb them at an early age and are affected by them. Two stereotypes push young girls away from computer science. The first is about the culture of computer science: who belongs in computer science and what do they do? One popular image of computer science is "nerdy" men who sit alone coding all day. We need to redesign classrooms and change the media stories about computer science. If we can show a broader picture of who belongs there, we can get more girls involved. The second stereotype that shapes the gender gap in computer science is about ability. The idea persists in North American culture that boys are better at math and science than girls. Master et al. (2016) found that children believe gender stereotypes about math and technology as early as second grade. By the time girls get to high school, the belief that they are less talented in computer science is already deep in their minds. “Why risk trying something new when the cultural stereotype predicts they won’t succeed?” (Master et al., 2016, p. 6).

Before moving further, it is vital to first have a look at factors that most studies researched identified as issues, as well as relevant solutions. A review of literature on women’s low participation in computer science, Sapna, Andrew, and Saenam (2011) analyzed key factors from three perspectives: psychological explanations, social factors, and structural factors. Below is a summary of their key findings.

Psychological Explanations

Psychological explanations are discussed below regarding academic stereotypes and gender stereotypes. The stereotypes discussed include images of computer people, science work, poor awareness of computer science as a discipline and a career, and perception of computer-related subjects as ‘unattractive’ and boring (Couderc, Parsjö & Röning, 2015).

Do stereotypes found in popular culture shape women’s decisions to go into computer science? This is the question that researchers Margolis and Fisher (2002) wanted to answer. To answer this question Margolis and Fisher (2002) examined undergraduates’ stereotypes of the people in computer science and whether changing these stereotypes using media might influence women’s interest in computer science. In the first study, college students at two U.S. West Coast universities ($N = 293$) provided descriptions of computer science majors. The findings revealed that computer scientists were perceived as having traits that were incompatible with the female gender role, such as lacking interpersonal skills and being singularly focused on computers (Sapna, Andrew, & Saenam, 2011). Based on their analysis of the data they collected, it is clear that the assumptions people hold of those involved in computer science contrast with the stereotypes associated with women and traditional femininity. This is important because women need to see themselves working and living in the field of their choice; female stereotypes drive women away from the computer science field (Henry, 2013). In the second study, college students at two U.S. West Coast universities ($N = 54$) read fabricated newspaper articles about computer scientists that either described them as fitting the current stereotypes or no longer fitting these stereotypes. Women who read that computer scientists no longer fit the stereotypes expressed more interest in computer science than those who read that computer scientists fit the stereotypes. In contrast, men's interest in computer science did not differ across articles. One key takeaway from this research, is that it may take very little to persuade women that computer science as a legitimate career choice. Taken together, these studies suggest that gender stereotypes of academic fields influence who chooses to participate in these fields, and that recruiting efforts to draw more women into computer science would benefit from media efforts that alter how computer scientists are depicted (Sapna, Andrew, & Saenam, 2011).

Let's dig a little bit deeper into some of the psychological barriers that women face when it comes to entering into computer science. For some women, they may come to believe that men are simply 'naturally' better suited for this kind of work. Here is one woman describing her beliefs about computer science as a woman: "Oh, my gosh, computer science isn't for me. I don't dream in code like they do" (Margolis & Fisher, 2002, p. 69). The psychological belief expressed here, grounded in traditional gender stereotypes, clearly would disadvantage any woman who thought of entering computer science as a career. The idea being that they feel as an outsider simply someone who did not fit naturally with this field. The above findings really raise questions about how far we have really come in the past 40 or 50 years when it comes to promoting women in science. In the classic study on perceptions of scientists, Mead and Métraux (1957) asked 35,000 U.S. high school students to write an essay describing their image of a scientist. The dominant image that emerged was a middle-aged male who wore glasses and a lab coat and worked alone running experiments. Many would agree that we can do much better.

While some computer science stereotypes may be representative of a majority of members and critical to membership (e.g., knowing about technology), others may be more peripheral and less accurate (e.g., liking science fiction), for example being technology-oriented. This stereotype involves a perception that computer scientists are technology-oriented, with strong interests in programming and electronics (Cheryan et al., 2011b) and little interest in people (Diekman et al., 2010). The perception that computer science is technology-oriented rather than people-oriented may cause some women to express less interest in the field than men (Diekman et al., 2010). This is in large part because gender stereotypes teach women to be weaker in science and technology, to be more interested in the social world, while academic stereotypes inform women that computer science people are 'nerdy' and 'boring.'

Other psychological barriers in regards to stereotypes also nudge women away from computer science as a career. For example, there exists a stereotype that computer scientists are singularly focused on technology and that they are obsessed with computers and programming to the exclusion of other interests (Beyer et al., 2003). Claims that computer scientists were "born coding" or "dream in code" reflect this presumed singular focus, but also that such interests are innate. Computer scientists are stereotyped as having an "obsession with machines" (Beyer et al., 2003, p. 52). Just like the well-known character Sheldon in *The Big Bang Theory,* computer scientists are presumed to be men who works alone in a laboratory all week, addicted to coding or debugging. His time spent presuming his computer related obsession, regardless of the time and environment, only with burgers or instant noodles for food. Running alongside the notion that computer scientists are singularly focused, the stereotype also promotes the idea that computer scientists lack interpersonal skills and are socially awkward (Mercier et al., 2006). This stereotype has been endorsed by undergraduates (Beyer et al., 2003) and by high school students in the U.K, for example (Schott & Selwyn, 2000). Even middle school students are aware of this stereotype (Mercier et al., 2006). Stereotypes that computer scientists lack interpersonal skills can be contrasted with expectations that women are socially competent and people-oriented (Diekman et al., 2010), which may convince women that they do not belong to the computer science world. Computer scientists are stereotyped as “intelligent” (Beyer et al., 2003, p. 49), “genius” (Schott & Selwyn, 2000, p. 298), and “logical” (Schott & Selwyn, 2000, p. 292), which tend to be connected to a masculine stereotype. The pervasive stereotype of computer scientists as being ‘nerds’ or ‘geeks’ further conveys the notion that they are smart (Beyer et al., 2003), but also ‘uncool’ to a certain degree. This connection between computer science and “nerdiness” is portrayed in U.S. media (Mercier et al., 2006). These descriptions are quite masculine based on the gender stereotypes, as reflected in the popular TV show *The Big Bang Theory*. It’s worth mentioning now, stereotype also links very closely the idea of scientist, with whiteness. In this sense, there is a racialized dimension to this stereotype whereby people of color, non-whites, also fail to see themselves reflected in the idea of being a computer scientist.

Another psychological barrier, perhaps less harmful than in the past, was one that reflected physical features. When students come up with an image of a computer scientist, they tend to imagine a male who is unattractive, pale and thin, and wearing glasses (Mercier et al., 2006).

Imagine Bill Gates, for example, as the quintessential example. This particular stereotype may influence whether or not women decide to enter into the computer science field. Overlapping with other stereotypes, women and girls just may not see themselves in this particular area (Cheryan & Plaut, 2010). Before we move on, there has been something of a small change when it comes to representations of computer scientists in popular culture. Emerging perhaps out of the myth of Steve Job's superhero, we see other representations of computer people as superheroes including Tony Stark from *Ironman* fame, and Elon Musk, the founder of Tesla and other tech innovations. To some degree, the computer scientist has become a superhero within popular culture, with a deeply assumed masculine nature.

Above are academic stereotypes of the computer science field. However, when choosing a major, women not only consider required classes and career prospects, but they also compare themselves to those currently in the field for clues about whether they belong and would be successful there (Creamer et al., 2007). Because the female gender stereotype influences the way women see themselves (Eagly, 1987), the perceived incompatibility between computer science stereotypes and the female gender role compromises women's sense of belonging and discourages them from pursuing these fields (Diekman et al., 2010).

For example, math self-efficacy is reflected in gender stereotypes. When women are faced with program choice, one assumption that makes them reluctant to major in computer science is that "science is hard." This ill-defined nature of computing results in computer science being unattractive to women. Palma (2001) and Sanstad (2018) both researched the fear of science in women. Sanstad (2018) notes that the concept of "science is hard" is widespread and constant for many students entering a science course. This is quickly becoming a critical issue in education during a time in our world when we need to increase the numbers of well-qualified scientists.

The fear of science is due to a low mathematical self-efficacy in women. Many hold a belief that the computer science field is math intensive. Regardless of whether it is true that women are weak in mathematics, we need to figure out the relation between computer science and mathematics first. One boot camp graduate in Seibel and Veilleux's research said that

> since you bring up math, I do think that was also maybe part of why I never thought about coding because I did have this idea in my head that you needed to be good at math to be a software engineer and in practice, you really don't. Ironically, now none of the graduates from either the computer science or boot camp programs are using advanced mathematics in their current jobs. All emphasized logical reasoning is a necessity for being a competent coder. (Seibel & Veilleux, 2019, p. 8)

However, this argument does not include women working in artificial intelligence, robotics, or machine learning specialties, which definitely would require advanced math such as algorithms and often advanced degrees (Seibel & Veilleux, 2019). Now we can conclude that if a student does not intend to be the highest level of computer sciene, mainly in artificial intelligence, robotics and machine learning specialties, then strong math ability is not mandatory to enter into the field of computer science.

Educators and others have to tell these girls that they can make a difference in computer science. We must show them that computer science is for everyone, and not just a "boy thing." One way we can make this happen is to begin introductions to computer science earlier, before societal stereotypes really take hold in children. Introductions to computer science is necessary to "make it approachable" for young girls (Computer Science.org, n. d.) as many women are brought up with the "fear of science" (Hango, 2012). The University of California at Berkeley, for example, experienced a revolution in their introductory computer science classes. What used to be “introduction to symbolic programming” is now called “the beauty and the joy of computing.” Successfully, in 2014 women outnumbered men in the class for the very first time. Of course, this was a simple change that helped create a culture of acceptability for women and girls. However, educators need to think much more deeply about how they can create programs and cultures that are inclusive in particular focusing on marginalized women, women of colour in women coming from working class and working poor backgrounds. It will take much more than a simple name change to address this gender inequity (Computer Science.org, n. d.). Therefore, for computer science curriculum, the intro course name is something that can easily completed to encourage more women to enroll in computer science.

With the results of the studies, we have more detailed clues as to the potential solutions: we develop education programs that challenge gender and academic stereotypes found in the context of computer science, and/or we can also increase women’s self-efficacy in science subjects. Further research on the specific female community we are dealing with in computer science education is required. We have taken some time to look at the psychological factors that shape women’s experiences in computer science. Next, I begin to explore some of the key sociological factors that shape women’s experiences in computer science. Some of these factors include family, work-life balance, pay gap, peer pressure, classroom environment, and media.

Social Factors

Various social factors play a role in shaping women’s experience in computer science. One key sociological factor is the way women often work a ‘double-shift.’ Sometime ago, sociologists coined the term ‘double shift.’ The term was meant to describe how women often have to work full-time jobs, and then come home to do another shift in relation to childcare and other domestic duties (Rachel & Kongar, 2017). Men typically only have to do ‘one shift’ in the paid labor force and then come home to do relatively little when it comes to domestic labour. Of course, doing a 'double-shift' is not unique to women who enter computer science, as most women in the labour force tend to do the double shift, to ignore this factor in this paper would seem to me to be negligent.

Take China for example,working extra hours is a common phenomenon in computer science in China. This is true for both women and for men. However, as the family has different expectations for women than for men, women likely cannot accept this policy of working more hours. Because of the way gender structures the labour force and the family, children and parents expect women to take more care of the family and all other aspects of domestic labour (Baxter, 2000). So, in many ways, men do not have to think too carefully about a work/ life balance in the same way that women do. Men can focus on their careers, and pay much less attention to the domestic sphere, much less to child care. Keep in mind, men who make the decision to pay less attention to the family rarely face social consequences in the way that women do. This is not true of women. Women are often shamed by others if they choose to not give up their career. Being labelled a 'bad-mother,' in today's context is a constant fear of many women. One consequence of the way gender relations works in China and other places, is that women are pushed out of computer science as a career,as they are unable or unwilling to commit to the long hours at the expense of their family.

Sociologically speaking, it has been a long-established fact that women in general are paid less than men for doing the same job (Melconian, 2010). Alqadeeri (2019) showed that even in high-paying STEM Jobs, women earn less than men. In 2015, Canadian women who graduated with bachelor's degrees in STEM earned just 82.1% of the earnings of their male counterparts (Alqadeeri, 2019). Even after more than thirty years of equal pay legislation, women in the

European Union who worked in professional, scientific and technical activities earned 73.4% of what men did in 2014. Therefore, even if a woman succeeds in breaking through academic and gender stereotypes, and surviving the 'chilly' masculine working environment, she still only obtains a lower wage than that of a man. One of the key outcomes of this gender inequality is that women in computer science feel less valued, and are not likely to have the same level of self-worth relative to the company or corporation that they work for (Fuchs, 1986). What does it say about a corporation or company that pays women in general less than simply because they're women?

Some researchers (Maria & Leveson, 1995) also mention peer pressure as it relates to the learning environment. Women who have already enrolled in computer science programs usually have higher dropout rates than men (Bunderson & Christensen, 1995), and some of this is explained by the way men dominate classrooms. In the process of learning computer science, men who come across as "Know-it-alls" are well-known problems in classrooms (Seibel & Veilleux, 2019). Boys learn early the gendered lesson which is to be verbally active and to show confidence in the classroom. Once they learn this lesson, boys occupy much of the verbal space, along with dominating student-teacher interactions as men. As such, girls often feel intimidated in these kinds of classrooms. As President Klawe (2017) of Harvey Mudd College said, "women were intimidated by male students who showed off in class" (p. 2). It is a well-known custom in the computer science field that men 'show off' their capability in front of the others. The pressure from men "know-it-alls" may lead to women leaving computer science especially when they still have a low self-efficacy of mathematics and fear of science. As Seibel and Veilleux (2019) put it as male "know-it-alls" create toxic environments as "knowledge parading" by confidently exclaiming that a concept was easy or by using complicated, although sometimes inaccurate, jargon. Clearly, the gender politics of the classroom shapes the experiences of women in a way that may ‘nudge’ many of them out of computer science programs.

While some women overcome this hurdle, they report the fear of appearing to have inferior knowledge and this, of course, impacts their self-confidence (Seibel & Veilleux, 2019). This is an interesting and strange phenomenon in the programing world both at the learning stage and in working contexts, although insiders perceive it to be natural. Male developers use this kind of technique to belittle others and even get promotions with higher payment (Wray,2010). Some coders benefit from this ‘male know-it-all’ behaviour with a higher payment as well as less contribution to the profession. For some other coders, mostly women coders in the learning period, male know-it-alls belittle these women and drive them away from computer science. Although, these women have already suffered a lot in the decision to enroll in computer science.

Sociological research has shown that when it comes to the computer science field women often feel like ‘outsiders.’ Women don’t feel like they fit into the gendered culture. Reflecting on my experience, women in general don’t feel like they belong to the computer world in the same way that men do. Reflecting back on my coding experience, I felt as a woman that I was something of a mis-match when it came to fitting in with the culture. I was constantly in a gendered tension which produced the ongoing question- Do I belong here? Of course, this is not uncommon for women as they move into other traditional male spheres. Jane Margolis (1994), an education researcher at UCLA, said that "it was not a question of capacity or ability. It was a question of women feeling that they weren't welcome or that their existence was suspect" (p.4). It’s not surprising then that, gender disparities in interest and success in the stereotypically designed computer science classroom originate from women’s weak sense of belonging in that environment. “One way environments affect students is through identity cues, or structural elements that communicate who belongs in that environment" (Cheryan, Plaut, Davies, & Steele, 2009, p. 6). For example, when a computer science classroom contains objects or materials that are male centric, that typically only represent men, such as *Star Trek* posters, video games, and space shuttles, female students may be less interested in computer science than their male peers (Cheryan, Meltzoff & Kim, 2011). Creating an exclusive classroom that does not make women feel welcome certainly sends a strong gendered message to students - women do not belong: "Not feeling like one belongs in an environment has a detrimental impact on learning" (Pittman & Richmond, 2008, p. 6). However, this particular problem isn't insurmountable. Changing the physical culture of the classroom just requires educators to not only be culturally responsive, but to also be attentive to the social cues of the objects and materials they use (Fraser, 1998). A classroom that is built on a physical culture that reflects the diversity of the student population, that promotes inclusion would be a step in the right direction. A well-designed classroom would contain positive representations of men and women, and go to some extent to preventing women from dripping out of the pipeline.

Computer science often creates 'chilly' climates for women and girls (Roldan, Soe, & Yakura, 2004). Although I have spoken about this in a roundabout way earlier, I thought it would be worthwhile to develop this idea just briefly. Chilly climate are the ways in which women and girls are made to feel unwelcome. In the past, this has happened in traditional male professional spheres like politics, medicine, law and engineering. Women face a variety of barriers including sexist micro aggressions, but also include sexual harassment and sexual assault (Solorzano, 1998). When men create cultures that developed the conditions whereby women and girls feel unsafe, women tend to leave. They simply don't want to put up with the everyday hassles just to go to work. The computer world in general, online environments included, tend to be places that are unwelcoming for women and girls (Hinduja & Patchin, 2008).

But let's not forget about another powerful source that shapes the attitudes of men and women when it comes to the labour market in general and computer science in particular: Media. Research has demonstrated that media, popular culture, and advertising also make a contribution to nudging women away from the computer science field. Sapna, Caitlin and Lauren (2013) argued that the way a social group is represented in the media influences how people think about that group and their relation to it. For example, undergraduate women who watched gender-stereotypical commercials in which women excessively focused on their appearance subsequently exhibited less interest in technical careers than those who were not exposed to these commercials (Davies et al. 2002). Sapna, Caitlin and Lauren (2013) also discussed in their study that movies such as *Revenge of the Nerds* (1984*)*, *Weird Science* (1985), and *War-Games* (1983) promoted the image of the "computer nerd" during the 1980s largely as a male construct. Nonetheless, in these, films the male 'nerd' was able to envision access to power and privilege through computer science. Once the power was accessed, these young men no longer had to be 'nerds' and face the bullying of the 'jocks', and as such became 'real men.' In many ways, these films seduced young boys into the computer science field through the promise of status, wealth and power. And, boys listened. Not surprisingly, this trend coincided with the beginning of the decline in the proportion of women pursuing computer science in the United States. Keep in mind, that this trend also coincided with the rise of home computers and emerging and powerful computer corporations like Microsoft and Apple. Unlike the 1970s, there was now an enormous amount of money to be made in the computer science field. So, with access to high wages and income and wealth, men paid close attention to the emerging field of computer science.

But let's discuss a little more the relationship between the field of computer science, gender and popular culture. Within the context of popular culture, the linkage between the idea of a computer nerd and masculinity has not gone away. The hugely popular show *The Big Bang Theory,* exploits the idea ofthe computer nerd and masculinity. The television show profiles graduate students in physics and engineering who look and act in ways consistent with computer 'nerd' science stereotypes. They're socially awkward, with little experience with women, they do not care for athletics or sports, they are not physically strong or intimidating, and in many ways come across as little boys, immature and still playing with their toys with other boys. These media representations are especially troubling considering that children report that television, movies, and magazines constitute their primary source of information about what scientists are like (Steinke et al. 2007). Such media depictions may cause students to believe that these characteristics are not only typical but even required of people in the field. As a result, women who do not fit the current stereotypes may be discouraged from developing an interest in these fields even before they have a comprehensive picture of computer science subjects.

These academic stereotypes of computer science people and work, as well as, the subject itself, are incongruent with characteristics women are expected to have in gender stereotypes and may wish to possess (Augereau, Iwata, & Kise, 2018). A negative consequence of the circulation of these stereotypes in society is that they prevent women from developing an interest in these fields, and therefore tend to 'drip' out of the pipeline.

Structural Factors

Various structural factors lead to women's low participation in computer science. These include inadequate curricula, teacher's perceptions, and computer access. These are the issues I will now explore. I begin with some thoughts on the curriculum.

The curriculum found in computer science programs are often deeply gendered. The computer science textbooks, for example, are always full of "boy things." For example, the textbook for class XI, "*computer science with C++*", mostly use gender-coded colours like black, blue and grey, which make some girls feel like they don't belong to the computer science field. Keep in mind that using gender coded colours such as these also provide a welcoming culture for boys. We know that boys tend not to gravitate to brighter colors such as pink and purple, as they are closely linked with traditional femininity. So, the writers of textbooks use colours that make boys feel at home with their masculinity. What is worse, the content is full of recondite formulas, computer chips, the outer space, and abstract geometric images. All of these are far away from girl's expectation formed by gender stereotypes as girls (Galambos et al., 2009). What the above examples demonstrate, is that knowingly or not, textbook writers include material in their work that at some level appeal to boys, and certainly does not work to disengaged them. This shows that writers of textbooks have been much more interested in the success of boys than girls.

If educators are serious about preventing women from leaking out of pipeline, then it is necessary for computer science to be "approachable" (Computer Science.org, n. d.). if educators and others make computer science approachable for girls this may help alleviate their "fear of science" (Hango, 2012). Educators and others would be wise to show girls that computer science is for everyone. Therefore, an introductory to computer science course is critical, especially before societal stereotypes take hold. A good example is Harvey Mudd College, which is a school for students who are interested in science, math and technology. In 2006, there were only about 10 percent female computer science majors at Harvey Mudd College (Sydell, 2017). As Sydell (2017) described, after Maria Klawe became the president, she changed the name of the intro course, which had been called “Intro to Java” — a programming language into “Creative Problem Solving in Science and Engineering Using Computational Approaches.” At least before women step into the computer science field, she tried to reduce the fear from the course name as much as possible. “Harvey Mudd' s intro computer class became among the school's most popular. Now, instead of 10 percent, the number of women computer science majors ranges between 40 percent and 50 percent in any given year” (Sydell, 2017). The University of California at Berkeley also experienced a revolution in their introductory computer science classes. What used to be “introduction to symbolic programming” is now called “the beauty and the joy of computing.” Successfully, in 2014 women outnumbered men in the class for the very first time. (Computer Science.org, n. d.) Therefore, for computer science curriculum, the intro course name is crucial to preventing women from leaking out of the pipeline, and encouraging more women to enroll in computer science.

In educational context, teaching practices are influenced by teachers’ perspectives and beliefs (Cheung, 2012). However, teachers themselves likely have been cultivated with gender stereotypes, and later they become the agents of spreading these gender stereotypes (Weinburgh, 1995). They may teach students in a way based on gender stereotypes which they take for granted (Streitmatter, 1994). Therefore, in the preparation of teachers, one principle is to “create an equal learning environment” with “a knowledge of difference and a commitment to breaking down stereotypes” (Martino, 2011, p. 10). Educators need to engage female students and bring them into class discussions (Computer Science.org, n. d.). In this way, teachers will “build respectful and caring relationships. (Martino, 2011, p. 10) As an educator, in order to improve women’s participation in computer science, changes can be made in the introductory to computer science courses, teaching practice, and teaching with equity. The most important is that all these changes should be done in early childhood education before students are engrained with gender stereotypes (Master, Cheryan, & Meltzoff, 2016).

Another factor which matters in women's decision to major in computer science is their computer access, or rather, prior coding experience. Seibel and Veilleux (2019) found that five of the CS graduates took formal CS courses before college, and all participants had done some coding before college. Women with prior coding experiences are less influenced by the lack of mathematics. They have higher self-efficacy as they have been exposed to how computer science works. They will feel more comfortable in the scientific context. This factor also shapes women's academic interest in computer science. Nevertheless, there are still some women "who had experienced coding activities before high school (8/9 CS majors and 5/9 boot camp graduates) did not seem to extrapolate more accurate information about their abilities or the requirements of the field" (Seibel & Veilleux, 2019). Taking the above two factors into consideration, I argue that educating women to have a scientific and comprehensive understanding of computer science programs in high school or even earlier before they make a decision for post-secondary education is urgent and necessary. One solution is to create a mentorship program, bringing in speakers, or using female leaders to instill confidence in girls (Computer Science.org, n. d.).

A related area of research is the study of gender differences in computer attitudes, which are widely assumed as key predictors of the intention to pursue computer-related studies and occupations (Sainz & Lopez, 2010). The study shows boys usually have fun with computers, see them as toys and have a special interest in the 'technical' and 'mechanical' aspects of computers. As mentioned earlier, this phenomenon is largely explained by the ways in which computers have been marketed and sold to boys largely as toys. Boys from an early age engage in computer practices with other boys playing a variety of kinds of games. This cannot be said about girls and their experiences with computers. Conversely, girls then, are often deemed to view and use computers more instrumentally- as a 'mere' tool- and are more interested in computers' communication possibilities. The literature links this lack of enthusiasm towards computers to a low trust in their own skills: girls systematically undervalue their technological skills compared to what they really know and show much less trust in themselves (Meelissen & Drent, 2008).

A Glance at the Research

When we review relevant literature on factors like curriculum and teaching practice, teachers' perspective, we have noticed that some measures have to be taken at an early stage before the gender stereotypes take hold. This is true not only to the beneficiaries of the measures, but also to the administers of the measures like teachers or policy makers. Therefore, when we conduct research on how to increase women's participation in computer science, we have to make it clear which group of women we focus on, the "new" women who are seldom exposed in the environment of gender stereotypes and academic stereotypes or the women who have been immersed in gender stereotypes and academic stereotypes. When we come up with solutions, who will be assigned to administer them? The people who are rooted in gender stereotypes without noticing or the people free from influence of gender stereotypes.

Above factors which are researched in preceding studies, in fact are not discrete from each other. Some of them even intersect with each other or overlapped. Researchers discussed about the superficial presentation of some common ideas behind those factors, which lead to the failure of increasing women's participation in computer science after huge quantity of research and measures. With reference to the preceding discussion on factors contributing to women's underrepresentation in computer science, “the overall picture is a contradictory one: optimistic with respect to what we call women and ICT (that is, women as users) and pessimistic with respect to women in ICT (that is, women within the ICT professions)” (Faulkner & Lie, 2007, p.158). Superficially lots of measures are taken and policies are made, but gender stereotypes and academic stereotypes are still manipulating the IT world to drive women away. From this point, in order to find out the core problem of those research, first we will look into the eyes from which the researchers are conducting their studies. Dominant framework for researchers to explain women’s under-representation: leaky pipeline metaphor.

> The dominant framework that seeks to explain the fact that women are under-represented in computing is usually condensed through the metaphor of a ‘leaky pipeline’. This metaphor encourages us to see a pipeline carrying students through different educational stages to high positions in academy and in industry and to characterise the problem as a flow of girls/women diminishing over the stages. (Anna & Andriana, 2015)

Thus, all relevant research is focused in exploring why girls or women do not enter into the IT educational pipeline and why they do not persist, advance or remain in the field. (Anna & Andriana, 2015) Therefore, what most studies have in common is the aim to identify the factors that explain the leaking at each transition point (Anna & Andriana, 2015). It makes us only notice the superficial problems instead of the philosophy and belief behind it. The model is designed with some presumptions. The best-known critiques are those regarding the leaky pipeline model’s linearity assumptions and ‘supply-side’ focus.

Supply-Side Focus

Bartol and Aspray (2006), Bennett (2011), and Webster (2011) highlight that the metaphor focuses the problem primarily on girls’ and women’s lack of desire, knowledge of science and technological career options. It ignores how the demand-side account for the low proportion of women in computer science. Generally speaking, it requests reflections and adjustments about the cultural, structural and institutional arrangements that obstruct - girls and women's paths into IT. "This critique is very important to making researchers aware that the problem will be solved not only by supplying the pipeline with more women but also by changing the institutional and organizational arrangements that constitute the pipeline itself" (Webster, 2011).

Furthermore, girls and women are described as "failing" to enter the pipeline or as being deviant from a 'normal' relationship with computing in terms of their attitudes, skills, practices, interests and aspirations; the pipeline advocates a 'normal' relationship with technology-that is, boys' and men's relationship with computing. This conception assumes that "equality" means pushing women to comply with a male standard. According to this point of view, not only relevant interventions but also research fail to address the core problem that may cause the inequalities challenged by the study of women's low presence in computing. However, the dominant research remains untouched precisely in those nuclear dimensions. Mainstream research continues to document gender differences in computer uses and attitudes as the key barriers to entering computing (Abbiss, 2008).This feels like the metaphor provides superficial solutions by either providing sweaters to girls and women to survive in such a cold place or promoting the implementation of programs to turn up the thermostat, such as a more appealing curriculum, achieving a critical mass, working conditions, support networks, and thus to make the environment more attractive, supportive and friendly to girls and women. The core of the problem remains isolated and the gender and computing relationship is reduced to just an environment problem. We need to come up with other lines of research in the field through shifting our eyes and getting out of the metaphor model. We should have more clues about how to research on women's low participation in computer science.

A Glance at Computer Science Elsewhere

Instead of asking primarily 'why there are so few women in computing', we cannot continue to ask how computing has become 'masculine' and what this masculinization tells us about the historical and social construction of computer knowledge and specialties in North America (Ensmenger, 2010). First, it is important to be aware of the fact that most research is conducted on white-women and STEM (Ceci, Williams, & Barnett, 2009). So, we need to ask what is the situation of women of colour, women from working poor backgrounds, in computer science? The cultural difference is the key. In the U.S., computer science is culturally regarded as a "male" field. In comparison with Canada, where women comprised ~27% of CS enrollments during the years 2006 to 2010, that number was below 20%. Usually we assume the proportion of women in STEM is a representation of women's status in a culture. For example, African-Americans and Hispanics, have a science, and engineering degree attainment rate of 11% whereas white women have a rate of 29%. However, the situation in other non-western countries such as India and Malaysia is noteworthy. Studies conducted in non-western countries show higher percentages of women than men studying and working in the fields of computing and ICT (Galpin, 2002). In India both men and women see the field as something for all genders, and people aspire to work in it accordingly. In India, increasingly more women pursue a bachelor's degree in computer science, where the field is even seen as being 'woman-friendly' (Varma, 2010a). Computer science is seen as particularly suitable to women because working in front of a computer means staying in an office on mental work, away and safe from the outdoor labor work (Varma, 2010b). It is also seen as a good career choice for its wage and the social status and prestige that it may bring to women (Gupta, 2012). In India, science and engineering, are seen not as a male domain but as something in which females are taught to work hard (Varma, 2011). In Malaysia, gender ratios in computer science education and IT industry are not merely compatible-sometimes they are even dominated by women (Lagesen, 2008). Computing and computer technologies seem not associated with specific masculine characteristics. Office technologies are closely associated with women. As Mellstrom states, the spatial segregation of what counts as female and male spaces seems to precede the gender codification of the technology (Mellstrom, 2009, p. 894).

The literature on women in computing is dominated by studies and discussions of computer science education equating computing with computer science degrees or studies. However, it is important not to think of computing as a single educational subject or profession, which may hide the complexity of the situation (Hayes, 2010b) and make a narrow definition of both computing and ICT in general (Clegg & Trayhurn, 2000). This narrow definition prevents us from seeing other educational and professional environments such as art and design, cognitive sciences, new media, biology information science and education or library science, where higher percentages of women are found (Corneliussen, 2012). Verges, Cruells, and Hache (2009) explain that more than half of the 302 women with expertise in technology that they surveyed do not had a STEM degree. Nowadays some women enter into computer science field in some original ways such as the post-baccalaureate coding boot camp. The narrow definition of computer science education and profession devalues women's contributions and fail to reveal a genuine view of what the information society is (Cukier et al., 2002). In this way, our research on women's participation in computer science actually is not comprehensive at all, which will decrease the generalization of the result. Broadening our horizon on computing and IT courses and occupations will result in alternative ways to enter computing and also further our critical thinking on gender and computing relations.

But keep in mind there are women in computer science right now. Even with a narrow definition of computing, it is possible to find women already in computing and IT. However, we do less research on those women than we did on those women who either did not enter or gave up computing. This will tell us something about how these women keep dripping out of the computer science field. As Verges (2012) claimed, the focus on explaining what excludes women from computing and IT has been so popular that inclusion processes have been largely under-researched. It is also necessary to figure out the factors explaining why some women choose to enter the computer science field, what makes computing attractive for these women, why some women persist in those studies (Lenox, Jesse, & Woratschek, 2012). However, some scholars have noted that inclusion is treated merely as a mirror image of exclusion processes, not as a process of its own (Faulkner & Lie, 2007). As Boivie (2010) demonstrated,

> Under the shadow of the leaky pipeline logic, some research shows how some factors that are said to exclude women from computing (e.g. a lack of parental or peer support, a lack of early exposure to computing and a lack od awareness about what computing is) are reversed or curbed in some biographies. In this sense, the dominant image that research provides about women who choose computer science can paradoxically reinforce women's exclusion from the field. Thus, we must pay analytical attention to women who enjoy and derive pleasure from computing and programming. (Boivie, 2010)

This group also includes women who do not want to be expected to bring communicative skills, a people orientation or emotions into the picture because, as Boivie (2010) says about herself, ‘I do not want to be the bearer of femininity, being some kind of moral compass, bringing other, better values into the area of computer science and IT’ (Boivie, 2010, p.21).

Conclusion

In this study, I reviewed research on key factors contributing to women’s low participation in computer science. In terms of psychological factors such as stereotypes of images of computer people, science work, poor awareness of computer science as a discipline and a career, and perception of computer-related subjects as ‘unattractive’ and boring, potential solutions are that we come up with education programs that challenge gender and academic stereotypes in computer science. Social factors such as family, work-life balance, pay gap, peer pressure, classroom environment, and media also play a role in nudging women and girls out of computer science field. Related solutions to this problem might be that the society eliminates gender stereotypes, beginning with education. Here educators and parents and caregivers can play a crucial role in helping children challenge traditional gender stereotypes that often flatten and narrow their lives especially when it comes to career choices. Moreover, companies should be nudged to provide equal wages to both men and women, thus addressing the salary wage gap. When women see that they are being paid the same amount for the work and labor as men, they will be less likely to leave the profession. They will feel valued by their employers. Let’s not forget about the media. The mass media play a huge role in shaping the attitudes around gender in computer science. Of course, there is no easy solution to this problem. This will require a comprehensive adjustment beginning with the writers who create the stories that appear on our screens. Hiring a diversification of writers to write our stories that appear on our screens would help, I think, in addressing this issue. Regarding the structural factors such as inadequate curricula, teacher’s perceptions, computer access, and type of usages, our educational system should design more inclusive curriculum and consider teachers' perspective of gender issues in teachers' preparation program. What is more, to educate parents with a comprehensive understanding of computer science subject would be a good asset in order to help more girls to get access to computer science and take it for granted.

Another key area that educators and policymakers would be wise to address would be in looking at the cultural conditions that nudge women and girls out of science and technology. This would be specifically addressing the issues around sexism, sexual harassment and sexual assault. Women historically have been nudged or forced out of profession because of these issues. It also sends a chill to women, encouraging them to feel like they don't belong, that they don't fit in the computer science field.

Finally, it goes without saying that socially, politically and economically it would be wise as a society to encourage women to enter in to the computer science field. One only has to wonder at how much talent and progress has been lost over time due to women's absence. Addressing gender issues, advocating for women and girls, attempting to fix the leaky pipe are issues that would benefit all people.

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Vita Auctoris

Xiu Tian was born in 1988 in Hubei province, China. She graduated from Hubei University of Technology in 2011. From there she went on to the University of Windsor, where she is currently a candidate for the Master's degree in Education at the University of Windsor and hopes to graduate in August of 2020.