The Underrepresentation of Female Students in Computer Science Programs

Debunking Structural Gender Inequalities in Academia

Yixuan Ma, Concordia University ’23

Abstract: Despite the shared recognition that ensuring equitable educational opportunities for learners of all genders is a fundamental social justice issue, computer science programs still encounter equity and inclusivity challenges. Aside from the unbalanced gender composition, female CS students also suffer from quotidian gender essentialism and a sense of isolation under a male-dominated paradigm. The disproportionate female underrepresentation in academia restricts women from pursuing high-paying computing careers and exacerbates alarming gender inequalities in society. In essence, it is of paramount importance to question who leaves women behind. This study reveals that the androcentric institutional culture, as well as its corresponding educational practices and resource allocation in North American universities, resulted in the massive underrepresentation of female students in undergraduate CS programs from 2000 to 2022. This can be explored through the normalized yet dubious masculine culture, gender-inequitable pedagogical methods, and the scarcity of female support mechanisms. These aspects constantly interfere with female students’ enrollment, retention, and achievement in this subject area.

Despite the shared recognition that ensuring equitable educational opportunities for learners of all genders is a fundamental social justice issue, computer science programs still encounter equity and inclusivity challenges (North & Longlands, 2019). Computer sciences (CS) refer to the development and programming of computer hardware and software (Page & Smart, 2014). It is one of the fastest-growing industries with substantial labor demand and lucrative career prospects. Although some female pioneers, such as Grace Hopper and Katherine Johnson, achieved notable success in computing from the 1950s to the 1970s, women have been largely absent in this field in recent decades (Dryburgh, 2000). In Canada, women accounted for 15.8 percent of first-year undergraduates in CS programs in 2010, and only half of them graduated with a degree in computing (Statistics Canada, 2019, Table 1). Similarly, in the United States, only 18.7 percent of CS bachelor's degrees were awarded to female students, while women represented 57.3 percent of degree recipients in other disciplines (National Center for Science and Engineering Statistics, 2019, Table 2-5). Aside from the unbalanced gender composition, female CS students also suffer from quotidian gender essentialism and a sense of isolation under a male-dominated paradigm (Charles & Bradley, 2006). The disproportionate female representation in academia restricts women from pursuing high-paying computing careers and exacerbates alarming gender inequalities in society.

Whereas some scholars attribute this underrepresentation to women's academic unfitness and preference for relational work, they may omit the institutional context of this issue, thereby risking oversimplifying the topic with a victim-blaming tendency (Varma, 2002; Varma et al., 2008). In essence, it is of paramount importance to question who leaves women behind. I argue the androcentric institutional culture, as well as its corresponding educational practices and resource allocation in North American universities, result in the massive underrepresentation of female students in undergraduate CS programs from 2000 to 2022. This can be explored through the normalized yet dubious masculine culture, gender-inequitable pedagogical methods, and the scarcity of female support mechanisms. These aspects constantly interfere with female students' enrollment, retention, and achievement in this subject area.

The Institutional Culture: Masculine as the Default

The CS faculty establishes masculinity as the default narrative, normalizing the underrepresentation of femininity and diverting female students away from enrolling in CS programs. This is evident through the analysis of two dimensions. First, there is an enduring masculine culture in computing faculties. In North America, through a seemingly neutral approach, the educational environment portrays computers as preferably for men, who are perceived as capable of controlling powerful machinery—a subject field "culturally overlaid with the aura of masculinity" (Clegg, 2001, p. 320; Varma, 2002). The widespread dissemination of this ideology corresponds to the mass media theory, representing an invisible, amorphous mass communication with a "*sit notum omnibus presentibus*" strategy—be it known to all present (Peters, 2010, p. 269). It conveys the masculine association to all individuals in the CS academic community, including the administrators, the instructors, and the students. Particularly, faculty members share a normative belief that computing is a male domain (Barker & Aspray, 2006). With the hierarchical relationship between educators and learners, many faculty members, who have the power to transmit knowledge, implicitly reproduce negative gender messages and consolidate the gender-essentialist epistemology through day-to-day student-faculty interactions (Barker & Aspray, 2006). Femininity is thus positioned as the inferior, insignificant opposite to the male-dominated narrative in the CS world, entrenching biases in the minds of the masses. In response to the overarching male-dominated culture, many female students either express outright rejection before entering the program or experience a sense of unbelonging upon entry (Cohoon, 2008), leading to dismal female enrollment in the CS subject. Secondly, this male-normed culture breeds gender-based disciplinary stereotypes

that underestimate female students' competencies. During student recruitment, program counselors tend to underrate female students' technological abilities, such as data information literacy, compared to their male counterparts (Barker & Aspray, 2006). Accordingly, they usually steer women away from science programs and towards other fields traditionally associated with femininity, such as arts and social science (Barker & Aspray, 2006). Under the gatekeeping efforts of educational authorities, female students go through bitter social-psychological enculturation and internalize negative judgments about their abilities. For example, even though male and female students perform similarly in pre-university mathematics courses, female students demonstrate increased self-doubt in calculus and information technology and are more likely to believe they are unqualified to study computing (Wasburn & Miller, 2008). Likewise, during a research interview regarding the presence of female "pathbreakers" in CS, a male student asserts:

> To be a woman in computer science? It is better if you change your major [to] something else … Just [like] the stories I've heard and the inside scenes from different professors, I don't think that they expect a woman to be in the computer science field. Nope. (Varma et al., 2008, p. 308)

The lack of sympathy does not simply denote an individual bias. Instead, approximately 20 percent of the respondents in the study, predominantly male CS students, echoed this statement. This uncovers the faculties' deeply embedded structural discrimination, framing the comprehensive computing culture in a narrow, monolithic masculine profile. The pervasive stereotypes elicit confidence crises for female students conceptually and hinder their enrollment in CS programs in a concrete way. This coincides with Joanna Cohoon's study (2008), which points out that the departments where most faculty report some female disadvantages are the ones with low enrollment rates of female students. As feminine voices have been overlooked by the faculty and repressed by female students themselves, gender-essentialist visions of masculinity and femininity, along with gender-typed preferences and prejudices, persist in the higher education system (Charles & Bradley, 2006). These problematic barriers generate a circular phenomenon—the more masculine and stereotypical the culture is, the more reluctant the female students are to enroll. This, in turn, intensifies the underrepresentation of femininity and renders the hegemonic androcentric regime possibly irreversible. Given these points, the male-oriented culture in CS faculties and the gender-based disciplinary prejudices combine to construct a solid foundation for the underrepresentation of female students in CS programs.

Pedagogical Methods: Gender-inequitable in Essence

In addition to the epistemological biases, the pedagogical methods in CS programs are also penetrated by gender injustices, undermining female students' retention in this discipline. In the first place, instructors tend to exhibit an imbalanced distribution of attention and encouragement among students of different genders. According to Lecia Barker and William Aspray (2006), instructors make less eye contact and provide fewer interaction opportunities for female students than male students in the higher education context. Instructors are also prone to share answers with them directly without adequate explanations, acquiescing female students to give up. Conversely, they encourage male students to figure out the answers themselves (Sadker & Sadker, 1995). The biased teacher-student communications not only lead to fewer opportunities for female students to improve and master computing skills, but also fall short of cultivating women's self-efficacy in pursuing CS pathways. This feeds female inferiority stereotyping and the pessimistic self-fulfilling prophecy, trapping women in almost endless vicious loops and de-equalizing their retention (Stanford University, 2015). Secondly, CS curriculums rarely consider the interest from a female perspective or in a gender-neutral manner. Notably, CS courses usually privilege agentic goals with a focus on self-directed learning and competitiveness. This disproportionately appeals to male students, who are likely

to be motivated by agentic goals; nevertheless, this overrides the interests of female students, who are more likely to be motivated by communal goals and collaborative learning environments (Yates & Plagnol, 2022). The disassociation of the curriculum from women's preferred academic development model provokes a loss of interest and increased uncertainty about their identity fitness, therefore discouraging females from continuing their studies. Equally important, current curricula feature positive associations with male portrayals in educational materials but fail to acknowledge female representation with equal efforts. In CS textbooks and teaching examples, portrayals of women appear less frequently in text and imagery compared to men (Giannakos et al., 2017). Even in the presence of female associations, they are usually depicted in a cynical and stigmatized light. For instance, most textbooks on cryptographic protocols involve a female character, Sybil. The name originates from Flora Schreiber's 1973 book *Sybil*, which tells the story of a woman diagnosed with dissociative identity disorder due to physical and sexual assault. This name is contextualized in teaching terminology as "Sybil Attack"—an attack in which forged identities disrupt a reputation system in peer-to-peer networks (Medel & Pournaghshband, 2017, p. 412). In like manner, David Munson (1996) illustrates that "the Lena image," a photograph from *Playboy Magazine* featuring a partially nude female, has been the standard stock image for image processing courses since 1973 (p. 3). The normative male gaze and insulting connotations in these course materials serve as a socio-political tool. It perpetuates the stereotyped preconceptions of women as the irrational, objectified "other" rather than intelligent individuals with the capacity to succeed in CS. Although many female students strive to resist stereotypical notions, it is difficult to counterbalance negative gender schemas that recurrently manifest in daily experiences. Everyday routine engagement with the materials exerts imperceptible yet incessant influence over them, deteriorating their self-perceptions, participation, and academic performances (Medel & Pournaghshband, 2017). As a result of long-term sexist socialization, the CS learning journey becomes an accumulation and internalization of female inferiority, hardship, and dismay, leading many female students to discontinue their undergraduate studies or transfer to other programs. Overall, the gender-inequitable teaching practices and the curriculum's unfair consideration of women's interests discourage female students during their studies and hamper their retention, hence consolidating the imbalanced gender representation in this discipline.

Resource Allocation: Female Support Mechanisms in Scarcity

The scarcity of female support mechanisms in CS programs further taints female students' university experiences with insecurities and fear, impeding their achievement of degrees in this subject area. First, most North American universities do not provide access to positive female role models for students in CS. Research by Stanford University (2015) illuminates that women constitute only 10 percent of most computer science faculties across the United States (para. 1). Female instructors, even senior female educators, experience different levels of marginalization and exclusion from advanced positions. This not only signals a shrinkage of feminine voices but also implies a deficiency in interactive same-sex mentorship availability and academic role models. Concurrently, universities feature minimal networking opportunities with female scientists and guest speakers from the industry. In fact, over 50 percent of students agree that having access to female role models is vital, as these role models can exemplify the accomplishments, salaries, and lifestyles associated with future job positions (Kim et al., 2011, p. 7). The exemplars can encourage women to envision themselves in similar occupations upon graduation and fortify the motivation to dedicate long-term effort throughout their studies. However, most students note that they have never met female technology professionals in university contexts (Wasburn & Miller, 2008). In this case, universities' limited acknowledgment of female professionals thriving in CS industries and academia provides inadequate incentive and anticipation of highly rewarded career prospects and life aspirations.

Female students thus tend to remain suspicious of the "return on investment" of their studies, questioning the chance of obtaining well-paid, stable employment opportunities in a male-dominated industry. Consequently, they feel less secure and motivated to complete the four-year intensive CS studies to achieve a degree that seems less promising for females. Second, coupled with the paucity of same-sex role modeling, universities' lack of female peer networks represents another persistent deterrent that erodes female students' achievement. In 2020, women made up only 19 percent of CS graduates with a declining tendency (United Nations, 2020, para. 2). This means that they sometimes have two to three like-minded technical women in computing classes whom they can ask for help with ease; though most of the time, they have none (Cohoon, 2008, p. 217). In the absence of same-sex classmates, women have to approach male peers for assistance. Many of them have been viewed as an anomaly by male classmates and encountered teasing infused with gender-essentialist contempt in the absence of institutional intervention (Varma et al., 2008). They are often perceived as girls with presumedly overemphasized feminine appearances rather than high intellectual and mental values. The consciousness of being female and the stereotype threat make them fearful of deepening their comprehension of course content through discussions. In particular, female students generally resonate with the statement: "Just that sometimes, I'm scared to speak or ask questions because guys might think … because I'm a woman, cause I'm a lady" (Varma, 2008, 304). This reveals that, with a severely imbalanced gender composition, communication among peers is no longer a chance for exchanging thoughts, discovering commonalities, and conjoining into a harmonious whole (Laywine, 2022). It is rather distorted into a socio-communicative struggle in which male and female students are situated at two opposite poles, triggering further gendering and misconceptions. In this androcentric environment, the unwelcoming climate for women is likely to provoke constant feelings of isolation and vulnerability. This also entails a reluctance to ask clarifying questions and participate in critical debates. The derived inactive, passive learning mode results in insufficient engagement and understanding of the courses, rendering many female students unable to make it through advanced CS courses to attain their degrees. This aligns with Cohoon's research (2008), which highlights that given the shortage of female-empowering networks, female students' attrition rate is six points higher than men's (p. 214). In general, because of universities' scarcity of female support mechanisms, including the paucity of positive role models and female student communities, women students' university experiences are permeated with career-related anxiety and interpersonal distress, besides a heavy academic workload. This undermines females' ambition and the pleasure of learning, limiting their attainment of degrees and personal development in the long run.

Concluding Remarks

Through analyzing the masculine paradigm in CS faculties, the biases in their pedagogical style, and the dearth of female support mechanisms that impede female students' enrollment, retention, and achievement, the drastic lack of female presentation in CS and the underlying rationales become evident. The androcentric institutional culture as well as its corresponding educational practices and resource allocation in North American universities give rise to the radical underrepresentation of female undergraduate students in CS programs from 2000 to 2022. These three dimensions form a nearly infinite cycle that worsens the structural underrepresentation of women, perpetuating gender disparities *in* education and, *through* educational socialization, in broader society. While this research primarily addresses the underrepresentation of women, it is crucial to interpret the ensuing conclusions within the framework of inherent limitations, encompassing considerations of representativeness and contextual specificity. Future studies may benefit from incorporating a closer examination of the obstacles encountered by women of color, trans women, and queer women in CS programs. This endeavor will facilitate a more comprehensive comprehension of this multi-faceted focal

point, where the interplay of gender, sexuality, race, and social norms converges to form an ultra-intricate amalgamation.

Today, some universities claim that there has been a proliferation of empowering campaigns for women in technology, which provide ample support for females to pursue CS pathways (Gallagher, 2017). Nevertheless, I criticize this notion, as the prosperous androcentric culture and stagnating gender composition in CS academics unravel that the educational gender gap is far from being eradicated. Gender-equitable education should not just be a rhetorical slogan. Universities should translate it into institutional improvements with socio-communicative empowerment and the provision of resources for females, equipping them with technological competencies and self-efficacy to fluidly navigate through the computing terrain. Ultimately, this will equalize gender representation among younger generations, advancing the integration of femininity into academic, technological, and sociocultural landscapes—a genuine liberating path toward a fair and inclusive future.

References

Barker L., & Aspray, W. (2008). The state of research on girls and IT. In J. M. Cohoon, & W. Aspray (Eds.), *Women and information technology: Research on underrepresentation* (pp. 3–54). MIT Press. https://ieeexplore-ieee-org.lib-ezproxy.concordia.ca/book/6267239

Charles, M., & Bradley, K. (2008). A matter of degrees: Female underrepresentation in computer science programs cross-nationally. In J. M. Cohoon, & W. Aspray (Eds.), *Women and information technology: Research on underrepresentation* (pp. 183–203). MIT Press. https://ieeexplore-ieee-org.lib-ezproxy.concordia.ca/book/6267239

Clegg, S. (2001). Theorising the machine: Gender, education, and computing. *Gender and Education 13*(3), 307–324. https://doi.org/10.1080/09540250120063580

Cohoon, J. M. (2008). Just get over it or just get on with it: Retaining women in undergraduate computing. In J. M. Cohoon, & W. Aspray (Eds.), *Women and information technology: Research on underrepresentation* (pp. 205–237). MIT Press. https://ieeexplore-ieee-org.lib-ezproxy.concordia.ca/book/6267239

Dryburgh, H. (2000). Underrepresentation of girls and women in computer science: Classification of 1990s research. *Journal of Educational Computing Research, 23*(2), 181–202. https://doi.org/10.2190/8RYV-9JWH-XQMB-QF41

Gallagher, B. (2017, June 16). *More women are studying computer science at Waterloo*. Waterloo University. https://uwaterloo.ca/math-alumni-newsletter/math-eties/feature/more-women-are-studying-computer-science-waterloo

Giannakos, M. N., Pappas, I. O., Jaccheri, L., & Sampson, D. G. (2017). Understanding student retention in computer science education: The role of environment, gains, barriers and usefulness. *Education and Information Technologies: The Official Journal of the IFIP Technical Committee on Education, 22*(5), 2365–2382. https://doi.org/10.1007/s10639-016-9538-1

Kim, K. A., Fann, A. J., & Misa-Escalante, K. O. (2011). Engaging women in computer science and engineering: Promising practices for promoting gender equity in undergraduate research experiences. *ACM Transactions on Computing Education, 11*(2), 2–19. http://doi.acm.org/10.1145/1993069.1993072

Laywine, N. (2022). *What is the communication?* [PowerPoint slides]. Moodle. https://moodle.concordia.ca/moodle/pluginfile.php/5653270/mod_resource/content/1/COMS%20205%20%20F22%20-%20Week%202%20-%20What%20is%20Communication_.pdf

Medel, P., & Pournaghshband, V. (2017). Eliminating gender bias in computer science education materials. *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, *17*(3), 411–416. https://doi.org/10.1145/3017680.3017794

Munson, D. C. (1996). A note on Lena. *IEEE Transactions on Image Processing, 5*(1), 3–4. https://doi.org/10.1109/TIP.1996.8100841

National Center for Science and Engineering Statistics. (2019). *Women, minorities, and persons with disabilities in science and engineering.* Retrieved October 28, 2022 from https://ncses.nsf.gov/pubs/nsf19304/data

North, A., & Longlands, H. (2019). Gender, poverty and educational equality. In M. J. Schuelka, C. J. Johnstone, G. Thomas, & A. J. Artiles (Eds.), *The SAGE handbook of inclusion and diversity in education* (pp. 103–115). SAGE Publications.

Page, D., & Smart, N. (2014). *What is computer science?: An information security perspective*. Springer. https://doi.org/10.1007/978-3-319-04042-4

Peters, J. D. (2010). Mass media. In W. J. T., Mitchell, & M. B. N. Hansen (Eds.), *Critical terms for media studies* (pp. 266–278). The University of Chicago Press.

Sadker, M., & Sadker, D. (1995). *Failing at fairness: How our schools cheat girls*. Touchstone.

Stanford University. (2015). *The shortage of female computer science faculty at Stanford University*. Retrieved October 28, 2022 from https://cs.stanford.edu/people/eroberts/cs181/projects/2000-01/women-faculty/intro.html

Statistics Canada. (2019). *Persistence and representation of women in STEM programs* (No. 75-006-X). Retrieved October 28, 2022 from https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00006-eng.htm

United Nations. (2020). *Closing the gender gap in science and technology*. Retrieved November 21, 2022 from https://www.un.org/en/un-chronicle/closing-gender-gap-science-and-technology-0

Varma, R. (2002). Women in information technology: A case study of undergraduate students in a minority-serving institution. *Bulletin of Science, Technology & Society, 22*(4), 274–282. https://doi.org/10.1177/0270467602022004003

Varma, R., Prasad, A., & Kapur, D. (2008). Confronting the "socialization" barrier: Cross-ethnic differences in undergraduate women's preference for IT education. In J. M. Cohoon, & W. Aspray (Eds.), *Women and information technology: Research on underrepresentation* (pp. 301–322). MIT Press. https://ieeexplore-ieee-org.lib-ezproxy.concordia.ca/book/6267239

Wasburn, M. H., & Miller, S. G. (2008). Keeping women students in technology: Preliminary evaluation of an intervention. *Journal of College Student Retention: Research, Theory & Practice, 9*(2), 205–219. https://doi.org/10.2190/CS.9.2.e

Yates, J., & Plagnol, A. C. (2022). Female computer science students: A qualitative exploration of women's experiences studying computer science at university in the UK. *Education and Information Technologies, 27*(3), 3079–3105. https://doi.org/10.1007/s10639-021-10743-5