An Inquiry into the Determinants of Female Representation in Computer Science

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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In this modern age of technology, computers have become ubiquitous within society. As a result, computer science and fields alike have grown in popularity over the last few decades. However, despite this popularity, an unmet demand exists for female computer scientists, and an overall underrepresentation of females in these fields of study (Teague, 2002). In a data collection from 2021 by the National Center for Education Statistics, in the graduating year of 2018 to 2019, females only accounted for 21% of the computer science degree recipients. Compared to the graduating year of 1985 to 1986, that same statistic was 36% ("Changing the curve," 2021). Due to this low representation, young girls become deterred from particular "learning opportunities and career aspirations (Cheryan et al., 2015, p. 1)" in computing. A purposeful approach is needed to revert the trajectory of this statistic and to close the gender gap in computer science professions consequently.

Given the presence of technologies, the growing demand for computer science professions, and the ability to code, it is essential to analyze the critical actors in the underrepresentation of female computer scientists and pinpoint a specific approach to achieve greater gender equality. This paper will analyze the historical trends of female representation in computer science majors, relating declines to their respective societal trends. Coupled with that, the personal and societal factors that influence one's decision to pursue or divert from a career within the computing field will be investigated. Through an adaptation of the Social Construction of Technology (SCOT) theory, this paper will identify how academic institutions and companies within the workforce can appropriately address the issue of achieving greater gender equilibrium.

BACKGROUND: THE GENDER GAP IN COMPUTING

In computing, there is a substantial disproportion between the presence of women and men. According to data collected from the Department of Education, in 2016, the female share of

computer science degrees was at a mere 18% when contrasted to 37.1% in 1984, which was the peak for this statistic. This statistic begs the question: What has changed over the past 40 years, despite societal progress towards gender equality, that has caused this particular academic field to become considerably disproportionate?

Investigating the respective historical trends is important to recognize the factors that have caused this sustained decline over the past 40 years. Specifically, detailing the growth of computers during this time frame as it coincides with these trends is pivotal. Referencing Figure 1, there are two significant time frames where the female share of computer science degrees experience a sharp drop, one in the mid-1980s and another in the early-2000s (Perry, 2018).

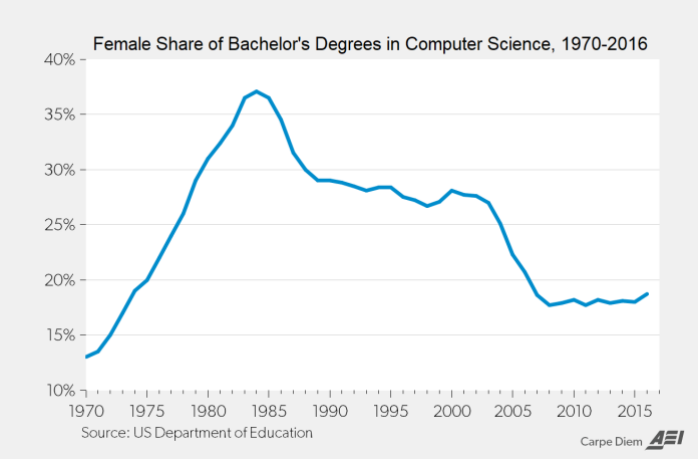

Figure 1: Female Share of Bachelor's Degrees in Computer Science. A graphical representation of the proportion of females in the field of computing from 1970-2016 (Perry, 2018).

Preceding the height of females in computer science, the introduction of the personal computer in the early-1980s led to this subsequent rise in student enrollment in computer science courses. However, by the late-1980s, a stricter reframing of the computer science (CS) curriculum was enforced to counteract the overflow of CS graduates due to insufficient demand for jobs (Patitsas et al., 2014).

Consequently, the idea of "weed-out" courses and the inclusion of GPA requirements disproportionately affected the participation of females and racial minorities within the field (Patitsas et al., 2014). Coupled with the retooling of the CS curriculum, the general decline following the mid-1980s can be attributed to the rise of personal computers and its marketing to

a primarily male audience. Personal computers at the time were viewed as and sold under the "boy's toys" category. The reasoning for such was the ability to play video games, an activity typically enjoyed by young boys. This masculine marketing contributed to the stereotypical view of computers being used by males. Thus, it allowed them to have prior computing exposure compared to their female counterparts in introductory CS courses (Magazine & Fessenden, 2014).

Following this initial decline in the late-1980s, the early-90s witnessed the computer science field become further masculinized. This period was characterized by the rise of video games with an absence of female role models in computing. As a result, there was a change in perceptions of computing, to be seen primarily as male-dominated, and a change in gender stereotypes. In the latter half of the 90s, society experienced the emergence of the World Wide Web, leading to a revival of CS enrollments for the second time. This period was nicknamed the "dot-com" bubble to reference the web and its positive effects on tech jobs and capabilities within society. However, similar to the mid-80s, the bubble soon burst in 2000, again generating a sharp drop in participation from CS students. The drastic decline is attributed to the stricter enrollment controls and reframing of the computer science curriculums that disproportionately affected females and minorities. With a more rigorous courseload and a more competitive atmosphere, many female undergraduates were deterred from pursuing that particular field (Patitsas et al., 2014).

SOCIETAL FACTORS AS A DETERMINANT

Despite the demand for computing jobs, there is no dramatic increase in the number of females in computer science, with no clear indication of why. Societal factors contributing to this gender inequality have been investigated, with one such reason being gender stereotypes,

particularly improper representations of people in computing emphasized in media (Mitchell & McKinnon, 2018).

The existing portrayals of computer science and engineering individuals typically fit the mold of an academically-inclined, socially-awkward male. Notable examples of this from popular media are but are not limited to the television show The Big Bang Theory and the film Real Genius (Cheryan et al., 2015). Exposure to these stereotypical media representations influences perceptions, even if that may be implicit. To support this notion, a study by Cheryan et al. (2015) investigated how stereotypes transmitted through media forms affect one's interest in computer science. Two groups of women undergraduates read two separate newspaper articles, one depicting computer scientists by current stereotypes and the other portraying computer scientists shifting away from those stereotypes. In comparison, "women who read the stereotypical article expressed less interest in majoring in computer science than women who read the non-stereotypical article" (Cheryan et al., 2015, p. 4). Despite the potential inaccuracy, stereotypes portrayed in popular media can shape one's sense of belonging and negatively influence future academic choices.

A sense of belonging is pertinent to one's confidence and positive outlook on career aspirations. A previous study by Cheryan et al. (2013) identified the mental effects on women from interactions with stereotypical and non-stereotypical male and female role models. Resulted showed that the women who interacted with the stereotypical role models felt a lower sense of belonging and a reduced interest in the field of computing when compared to the women who interacted with the non-stereotypical role models. Notably, from the research, the interactions between the women and role models were only, on average, two minutes in length, which speaks

to the extent to which small instances can hold great power over one's attitudes and perceptions (Cheryan et al., 2013).

The media's dissemination of gendered representations of these professions in the media discourages young females from pursuing such careers (Vitores & Gil-Juárez, 2016). Through a more purposeful representation of female scientists in the media, there can be a shift in the idea of females in this profession from being atypical to more widely accepted. Beyond career stereotypes, the misperceptions that have risen about the essence of computing as a consequence of it being male-dominated need also to experience a change in ideology to bring about fair representation (Teague, 2002).

PERSONAL FACTORS AS A DETERMINANT

The key to understanding the factors determining the number of females in computer science is to determine the most significant influences on a women's internal motivators. One's interest in a particular field is a guiding force when making academic choices; losing interest is an almost guaranteed deterrence. Furthermore, confidence in one's abilities and an acceptable feeling of belonging are needed when pursuing a career.

The idea that a sense of belonging is a direct indicator of one's subsequent interest can be supported by a study published in 2018 that investigated the role of introductory computer science courses in underrepresenting women and other racial/ethnic groups. Through a collection of data from undergraduate programs at 15 universities during the 2015 to 2016 academic year, results exhibited a direct correlation between a sense of belonging and "incoming student characteristics and college environments" (Sax et al., 2018, p. 1). To properly define a sense of belonging, this term refers to the feeling of acceptance given one's particular environment. Data was collected via a pretest and posttest survey at the beginning and end of the introductory

computing courses. At the beginning of these introductory courses, it was found that women disproportionately had a lower sense of belonging than their male peers, which became increasingly greater throughout the progression of the course. As such, this indicates that a sense of belonging can serve as a predeterminer of one's interest or deterrence in computing (Sax et al., 2018).

HARVY MUDD COLLEGE AS A MODEL

Identifying the precise reasoning behind the prominent gender disparity in computer science can be difficult. Some may argue that despite the demand for jobs, the supply of eligible females is insufficient due to a significant portion of females being represented in other fields and careers. Additionally, it can be argued that "the mere fact of having underrepresentation can perpetuate future underrepresentation" (Cheryan, 2015, p. 1). However, Harvey Mudd College, a small private institution in California, disproves the idea that a tangible solution does not exist ("Harvey Mudd College," n.d.). In the graduating class of 2018, 56% of the computer science graduates were women, a statistic almost three times the national average ("Harvey Mudd Graduates," 2018).

Beginning in 2005, this institution set in motion three practices to address the gender gap in computer science. These three changes focused on: interest, a sense of belonging, and confidence. To do so, a more comprehensive range of topics was introduced to create greater applicability for career aspirations and to increase appeal. Additionally, there was a greater emphasis on learning problem-solving skills for computational approaches to create a basis for introductory CS courses. The diversification of the CS curriculum increased the overall interest in the program and limited the deterrence following the beginning courses (Klawe, 2013).

To address the sense of belonging felt by the women undergraduates and their overall confidence, intimidation from differing experience levels was eliminated. Frequently males have prior exposure to programming and enter into introductory courses with more experience than their female counterparts. Therefore, instructors within the CS program discouraged those with more extensive experience from taking courses that were well below their skill levels. Doing so evened the playing field for undergraduates and ensured that students were taking courses appropriate to their skill levels (Klawe, 2013).

The efficacy of Harvey Mudd's three-part approach was significant; within a year of this being instituted, the representation of female CS undergraduates increased from "10 percent in 2005, to 20 percent in 2006," (Klawe, 2013, p. 56). Based on this, Harvey Mudd College can set the precedence for other academic institutions on how to accept the challenge of closing the gender gap in computing.

CONCEPTUAL FRAMEWORK DISCUSSION

The Social Construction of Technology (SCOT), a framework defined in 1987 by Trevor Pinch and Wiebe Bijker, focuses on how society shapes technology development. This conceptual framework relates how relevant social groups influence technology development within the current social structure (Klein & Kleinman, 2002). Considering the field of computer science and this idea of unfair representation amongst females, an adaption of the SCOT framework is illustrated in Figure 2. In this

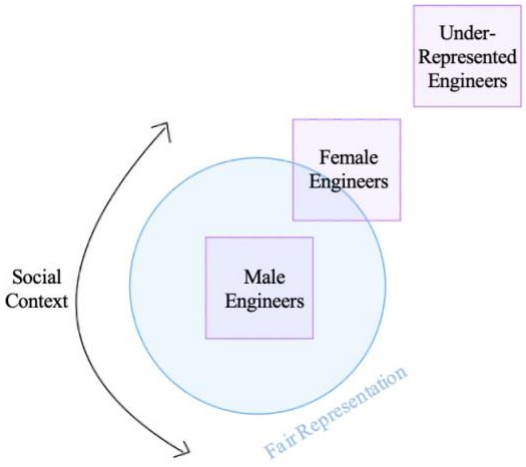

Figure 2: Representation in computing model. The 3 social groups are located in approximation to a boundary of fair representation that is shaped by the social context for those engineers (Adapted by Gould (2022) from Carlson, 2009)

figure, visualization is made to understand how the various social groups are represented as computing engineers.

To break down this model, the boundary of fair representation, in which male engineers currently stand, is defined by society and the perceived societal roles of those identified social groups. As such, the social context surrounds this model and is the key determiner of how these different engineers can enter within the boundary. While female engineers do have some representation, indicated by their location on the cusp of the boundary, the other under-represented engineers are far from equal representation, which is reflected by their furthest location in the model. This assertion concerning those who are under-represented is supported by a study by the Women and Information Technology Organization that identified that the computing workforce is constituted of "3 percent Black women, 2 percent Hispanic women and 7 percent Asian women" ("Changing the curve," 2021, para. 16).

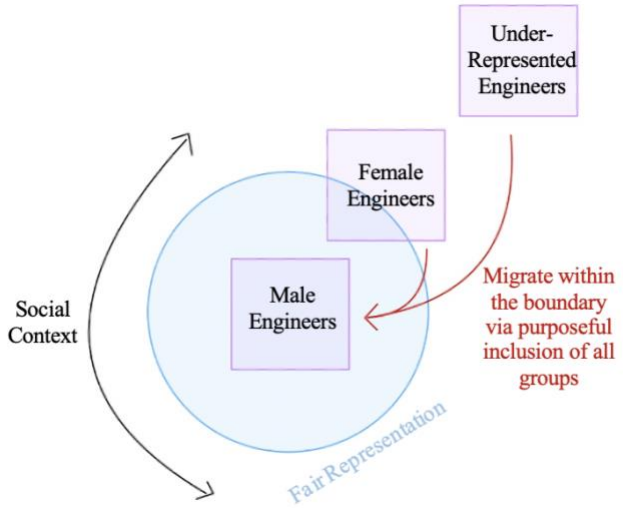

Figure 3: Representation in computing solution model. An approach to achieve migration within the boundary of fair representation is proposed (Adapted by Gould (2022) from Carlson, 2009).

Expanding upon Figure 2, Figure 3 illustrates a transition for the social groups outside or on the cusp of the boundary of fair representation to belong within that separation. The specific approach to achieve that migration is to be implemented by media, academic institutions, employers, peers, and society as a whole. Overall, an effort needs to be made to achieve positive shifts in societal role stereotypes.

By dismantling gender stereotypes in the media, females and other underrepresented groups can achieve a greater sense of belonging. This change sets the standard for accurately representing groups within computing, limiting overall deterrence for this major. Referencing Harvey Mudd College as an example, academic institutions can directly increase the supply of females in our current supply-demand dilemma in the computing workforce. While a demand exists from employers for females, there is simply not enough of them to achieve gender equilibrium. For employers and companies selling technology and computer products, a greater effort to market to a diversified audience as opposed to a primarily male audience and employ individuals from diverse backgrounds would effectively change perceptions of computing. Dedicated efforts to include all social groups are pertinent to fair representation.

CONCLUSION

The answer to why there has been a decline in the representation of females in the computing field is difficult to identify and a strategy to effectively oppose that trend is equally as hard. Several factors, both personally and socially, have played a part in deterring females and other underrepresented groups from this major. Some of those factors include but aren't limited to, gender stereotypes portrayed in popular media, inaccurate perceptions of computing, a lowered sense of belonging, diminished confidence, and lack of interest. To address these factors and any other potential demotivators, society should begin by disseminating non-stereotypical portrayals of individuals in computer science. Coupled with that, academic institutions can implement innovative changes to address the personal factors identified, using Harvey Mudd College as an effective example. Additionally, companies in this workforce can set a standard by employing a wide range of individuals from diverse sets of backgrounds, and ensuring products are marketed to a general audience. Multiple social groups are involved in this dilemma and should be equally

motivated to revert the trajectory of this statistic to achieve any sense of gender equilibrium within the field of computing.

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