Gender Disparities in Computer Science: Identification of Causes and Solutions

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Sadie Barton

Spring 2023

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

Advisor

MC Forelle, Department of Engineering and Society

<u>Introduction</u>

Although I cannot remember my exact response to the question, "What do you want to do when you grow up?" at the age of twelve, I know that it had nothing to do with computer science or technology. In fact, I had no idea what computer science actually was. Sure, I had heard of the term "coding", but in my young mind, code was a random assortment of letters and numbers that I would never have the ability to comprehend. Now, when my female relatives and younger sisters from see my code, as a computer science major, they have the same reaction. To continue, I lived in a very poor school district where no computer science courses were offered, and the lack of classes gave me the impression that the subject was not very important and thus out of reach. However, when I was finally exposed to hands-on coding at thirteen years old in a program outside of school, I discovered a passion for it and ultimately ended up pursuing a career in the field. Despite the fact that computer science courses are readily available in many school districts, girls still simply do not have as much interest in the field as boys, causing a substantial gender imbalance in the field.

As a twelve-year old girl in southwestern Virginia, my impression of computer science was that it was nerdy, difficult, intimidating, and an activity that was more fun for boys. Even then, without knowing precisely what computer science was, I knew that it was male-dominated in the United States. This is a problem because it leads to gender-related disparities in software-reliant products (Smith & Shonfeld, 2000). The consumption of software in the United States is not biased toward gender; men and women typically use the same software and typically engage in software for similar periods of time (Barnhart, 2022). One exception to this is video games. Males are notably more avid consumers of video games than women (Leonard, 2003). However, when you consider the options available, the reason is clear: most video games in the United

States cater to typically masculine interests, such as combat, sports, and automobiles. Game developers are obviously working to create a game that they would enjoy playing, and when this team of developers is roughly 80% male, the game produced is highly likely to cater to the interests of those male game developers. If the team was 80% female, they most likely would not produce a game to cater to those same masculine interests. Ideally, a gender-neutral team will lead to the most inclusive and innovative products, being that new opinions bring new possibilities.

Computer science is a large field that consists of many different subfields, including software engineering, computer networking, machine learning, artificial intelligence, cybersecurity, computer programming, game design, computer architecture, information technology, and database administration. Although some of these subfields are slightly less gender-biased than others, every subfield of computer science is significantly male-dominated in the United States. Notably, the highest paying subfields, including programming languages, computer science theory, and numerical computing, have the lowest percentage of female workers; the subfield of computer science theory is only roughly 13% women, and the subfields of programming languages and numerical computing are only roughly 14% women. The lower paying subfields, including software engineering, interdisciplinary computing, and human-computer interaction, on the other hand, tend to have the greatest amount of female participation; the subfield of software engineering is roughly 19% women, and the subfields of human-computer interaction and interdisciplinary computing are roughly 20% women (Maalouf, 2019). Notably, database administration was found to be the most popular computer science subfield among women, with women making up 39% of the field (LaBerge et al., 2022).

It is essential to understand which factors, including stereotypes and motivations, cause computer science to be so unpopular among women in the United States in order to address the gender imbalance of the field and resulting gender disparities in software. First, I will review literature regarding women currently within the field of computer science to determine any possible demographic correlations. Then, I will analyze literature regarding assumptions and opinions of computer science, as well as the factors and barriers that have an effect on career choice. Data will be gathered from both primary sources, in the form of a short questionnaire, and secondary sources, in the form of research articles and scientific journals. This data will be analyzed to determine which factors play a role in girls' thinking regarding computer science, specifically, as well as career choice in general. Overall, negative stereotypes involving girls in computer science and the lack of female role models and peers in the field cause many young girls to avoid the subject. Many girls feel no sense of belonging in the field of computer science. Additionally, many are unaware of the opportunities available in the field. Ultimately, girls need to be made more aware of the possibilities and their own potential in computer science when they are younger. This starts by eliminating those stereotypes.

Literature Review:

On average, roughly 80% of publications in computer science research in the United States each year have male authors. Additionally, there has been a general upward trend in female participation over the past few years, with an increase from 18% in 2004 to 23% in 2015. In 2000, the increase in male authors was 2.83% while female authors only increased 0.86%. However, in 2010, the slope of female participation rate began growing significantly faster (Agarwal et al., 2016). Despite this, with the current rate of increase, computer science research is not expected to reach parity before the turn of the century. It has also been determined that the

percentage of women authors in computer science research does not correspond with the percentage of women within the field so that they are not published representatively (Cheong et al., 2021). The issue does not apply globally, however; some countries, such as Albania, Bulgaria, and Macedonia, actually have a higher percentage of women in the field of computer science than men. In Kuwait, women make up roughly 80% of the field of computer science, causing an opposite gender imbalance (Galpin). This suggests that culture plays a significant role in career selection.

Research has determined that one important factor in the gender balance of the computer science field is the presence of stereotypes. Some children as young as age six, with differing demographics, have been shown to endorse stereotypes that girls are less interested than boys in computer science and engineering. The study also determined that stereotypes regarding gender-interest are endorsed far more by adolescents than stereotypes regarding computer science or engineering ability. Additionally, gender-interest stereotypes for an activity were found to decrease girls' interest in that activity. In this case, the stereotypes regarding gender-interest in computer science in the United States prevent many girls from developing an interest in the subject (Master et al., 2021).

It is important to understand what draws women to the field of computer science to better understand what steers them away. There is a unique profile of women that decide to pursue computer science degrees in the United States which displays notable differences between them and men that are pursuing computer science degrees as well as women that are pursuing degrees in other STEM fields. This profile was constructed by administering a survey to college students which contained questions regarding students' demographic information, prior academic achievement, self-ratings, and career aspirations, and analyzing the results. Interestingly, the

results indicated a greater racial diversity amongst female computer majors, with the lowest

percentage of white students than any other major. Other results indicate a relative low self-

efficacy regarding computer skills, academic ability, social skills, and leadership ability in

female majors in comparison to male majors. Women also rated themselves worse on physical

and emotional health than male majors, but better on measures of writing and artistic ability

(Lehman et al., 2016). The information obtained from the study can help paint a picture of how

some women feel about computer science. Additionally, it helps readers to better understand

women majoring in the field. Another study determined that men are more likely to believe

computer scientists are loners than women, which seems to suggest women in the field enjoy

group applications of computer science and may be more concerned with benefits in social

applications (Beyer & Haller, 2006).

Despite the marked differences between men and women in computer science, there are

some characteristics that they share. In order to investigate and identify the similarities between

male and female computer science majors and nonmajors with regards to view of computer

science, researchers distributed questionnaires to 56 students, in two different kinds of

technology classes: one that is required for the computer science major, and one that is not.

Then, 2x2 analyses of variances (ANOVA) was performed on the questionnaire results using

gender as one variable and major/nonmajor as the other variable. The results of the study

indicated that, interestingly, gender had no significance in interest in majoring in computer

science. Of concern, the study indicated that, although both male and female computer science

majors rated the compensation in computer science as roughly equal, nonmajor females rated the

compensation significantly lower than nonmajor males (Beyer & Haller, 2006). This indicates

that females outside of the field are likely more unaware of the high compensation and

opportunities in the field. Furthermore, this suggests that adolescent girls need more exposure to computer science so they are aware of all of the possibilities, especially considering computer science tends to be a relatively high-paying field, with the highest projected average salary for 2022 (Rivera).

Methods

I gather information about why computer science is relatively unpopular among women in the form of both primary and secondary sources. Secondary sources include scientific journals, such as the *Journal of Women and Minorities in Science and Engineering*, research papers, and books. In order to gather primary sources, I constructed a questionnaire and recruited participants on SurveyTandem. SurveyTandem is an online research platform that allows individuals to post surveys and receive responses based on the number of other surveys that individual completes. Ultimately, I decided that SurveyTandem was a good choice to reach my target audience, women between the ages of thirteen and twenty-two, given that it is primarily used by students completing research projects because it is a free platform (*SurveyTandem*).

Additionally, I had to consider the effect of bias on the questionnaire responses. In order to reduce response bias brought on by the agitation of committing a large amount of time or effort to a survey, I made the questionnaire only ten questions long, with eight multiple choice questions and two free response questions (see Appendix). Furthermore, despite the fact that I am looking for responses from only women, the first question of the questionnaire asks the participant their gender; this was done in order to eliminate any potential bias brought on by being singled out for gender (Warner, 1965). Although I received several responses from non-

females, their responses were not considered in the research because they were beyond the scope of the project. Overall, after completing a series of surveys, I received ten responses to my questionnaire from girls aged thirteen to twenty-one, with an average participant age of seventeen years old.

Analysis

Influence of Stereotypes:

Research has determined that one of the largest reasons women do not pursue a career in computer science are gender stereotypes regarding women in the field. The stereotypical image of a girl in computer science is seen as helpless, uninterested, and unhappy with the subject matter, almost appearing technologically inept (Master et al., 2021). In order to investigate these claims, researchers conducted meta-analysis using the PICOC (population, intervention, comparison, outcomes, context) method on girls aged 12-15 as well as computer science majors. The analysis consisted of 28 studies on the subject from several online databases, including SAGE Journals, Wiley Online Library, and APA PsycNET. A notable result of the study indicated that girls feel much less of a sense of belonging in computer science due to gender stereotypes (Spieler et al., 2020).

The decreased sense of belonging leads to a psychological phenomenon known as stereotype threat, in which individuals start to act according to a specified stereotype, effectively making it appear true. A direct result of this, in this specific case, is the relative lack of confidence in women in regards to computer science. This phenomenon has been shown to negatively affect high-school achievement in racial minorities as well as white girls (Seo & Lee, 2021). In my questionnaire, I asked the free-response question, "What do you know about

computer science?" In total, 60% of total responses were related to gender stereotypes, such as the relative lack of women in computing. One participant, aged sixteen, even responded, "It doesn't have much to offer for girls." Gender stereotypes surrounding the field of computer science, as well as the cognitive abilities of girls themselves, are clearly present and hindering the growth of the field.

Influence of Role Models

The relative lack of female role models in computer science careers discourages girls from pursuing a career in computer science, as girls more often pursue careers with female role models that they can look up to for encouragement (Ko & Davis, 2017). A study, which qualitatively analyzed a large number of publications regarding the topic, found that parental support and female mentors both have a notably positive effect on girls' interest in computer science (Kordaki et al., 2020). Another study investigating motivations in computer science, determined that encouragement from mentors correlated with a greater likelihood of pursuing a career in computer science (Spieler et al., 2020).

This suggests that girls may need more support and encouragement from mentors regarding computer science, perhaps due to inhibitions about their abilities due to existing stereotypes. While female role models do exist in the field of computer science, there are not nearly as many in the United States as widely known as males, such as Mark Zuckerburg and Bill Gates, within the field. Furthermore, as noted previously, women that do pursue a career in computer science tend to lack self-confidence regarding their computing and leadership abilities, making it more likely for men in the field to be denoted role models due to their more assertive attitudes in some cases. Overall, this research implies that exposure to female role models in

computer science at a young age could lead to positive outcomes in computer science in the future.

Influence of Social Motivations

Another primary reason that many young women do not consider pursuing a career in computer science is the manner in which young women tend to choose a career based on social contributions of that career field. Because women tend to struggle more to envision the social purpose of computer science and engineering, they are less likely to pursue careers in these fields. A 2-year ethnographic study was conducted to explore various domains of women engineers' experience with computing through semi-structured interviews, life history case studies, and participant observation. The participants in the study were 42 individuals that work in the fields of computer science and engineering at elite companies and universities. The results of the study indicate that one of the largest reasons women decide to leave the computer science field is that they feel the field does not allow them to help other people or make the world a better place. Additionally, the study determined that many women struggle to see the general goals of the computer science field (Carrigan, 2017). Another study determined that the most common reason for males to major in computer science is computer game interest; girls, on the other hand, were more likely to major in computer science based on a desire to use computers to make a difference in another field (Kordaki et al., 2020).

On my SurveyTandem questionnaire, I asked a question that read: "What is the most important factor to you when selecting a career?" Out of three response options, "maintaining a healthy work-life balance", "making a positive social difference in the world", and "earning a high salary", 70% of participants selected "making a positive social difference in the world".

20% of participants chose maintaining a healthy work-life balance as the most important factor, while 10% chose earning a high salary. This suggests that women are more worried about what they are doing with their careers and how they influence other people than earning high salaries.

Influence of Video Games

Video games have a considerable influence on a person's interest in computer science. One study determined that the manner in which video games tend to target a male audience was found to reinforce stereotypes that steer girls away from the field of computer science, marking it as an activity more suited for boys (Kordaki et al., 2020). As noted early, computer game interest is also the top reason for a male to participate in the field of computer science. The fact that most boys choose to major in computer science based on video game interest and the relative lack of female-targeted video games could explain part of the reason computer science is so unpopular among women. Also, video games have been found to be more socially isolating for young girls, which could contribute to negative social viewpoints of the field in females (Renner, 2019). The reinforcement of gender stereotypes in video games being produced only continue the cycle of gender inequality in computer science, like a never-ending loop that cannot be broken without a more diverse set of developers.

Influence of Adolescent Exposure

Girls' interest in STEM typically begins to decline around the age of 13-14, implying that the high school years are what discourage girls the most in STEM (Spieler et al., 2020). Additional factors that were found by the study to have a negative effect on girls' interest in computer science include the male dominance of computer labs and lack of female peers interested in computing. Ko and Davis (2017) studied the effects of a Seattle-based UB web

design course on high school students' impressions of computer science. The study concluded that the web design course had a positive impact on students' interest in computing and self-efficacy. Notably, 5 of 11 students described substantially different self-outcomes which incorporated computing. One student noted on her exit survey, "You definitely changed what I thought about computer science and web design. I love designing things, but I never thought one day I could design my own website in 6 weeks." This confirms that girls could greatly benefit from more exposure to computer science in adolescence to help mitigate the effects of gender stereotypes.

Additional Factors

I asked a free response question in the questionnaire that read: "What other factors are important to you when selecting a career?" Other factors that were found to be important include female peers in the workforce, good employee benefits, paid maternity leave, and fair compensation. Overall, many women have a desire to make a positive social difference in the world, and they need to be aware of the possibilities in computer science to do this. The social applications within computer science are only limited to one's own creativity. Additionally, because technology is shaped by human action, we need to ensure fields regarding technology are demographically diverse, so that the resulting product is equally pleasant for all social groups.

Conclusion

The male dominance of the computer science industry in the United States is a problem that has gone on long enough. Gender stereotypes regarding cognitive or physical abilities place unnecessary pressure on people, causing them to limit their abilities and never reach their full

potential due to stereotype threat. A future researcher could build off this project by

investigating the best form of adolescent mentorship for success in the field of computer science.

Furthermore, the project could also be built upon by identifying the best interventions for

eliminating stereotype threat, which could lead to benefits in many areas of an individual's life,

including computing confidence and ambition. Future research should look at ways to build

girls' confidence in computing, starting at a young age. Additionally, we need to consider ways

to increase exposure to computer science during childhood so that more people are aware of the

possibilities. Although many little girls question their abilities with computer science to the

point of never attempting to use them, they all have incredible potential and need to be more

aware of the possibilities in computer science, as well as their own potential, because those little

girls could write a program to change the world one day. With computer science, the

applications and possibilities are truly limitless.

References

Agarwal, S., Mittal, N., Katyal, R., Sureka, A., & Correa, D. (2016). Women in computer science research: What is the bibliography data telling us? *ACM SIGCAS Computers and Society*, 46(1), 7–19. https://doi.org/10.1145/2908216.2908218

Barnhart, B. (2022, March 2). *Social media demographics to inform your brand's strategy in 2022*. Sprout Social. https://sproutsocial.com/insights/new-social-media-demographics/

Beyer, S., & Haller, S. (2006). Gender differences and intragender difference in computer science students: Are female CS majors more similar to male CS majors or female nonmajors? *Journal of Women and Minorities in Science and Engineering*, 12(4). https://doi.org/10.1615/JWomenMinorScienEng.v12.i4.50

Bijker, W. (2017). Constructing Worlds: Reflections on Science, Technology and Democracy (and a Plea for Bold Modesty). *Engaging Science, Technology, and Society*, 3, 315. https://doi.org/10.17351/ests2017.170

Carrigan, C. M. (2017). Yearning to Give Back: Searching for Social Purpose in Computer Science and Engineering. *Frontiers in Psychology*, 8. https://www.frontiersin.org/articles/10.3389/fpsyg.2017.01178

Cheong, M., Leins, K., & Coghlan, S. (2021). Computer Science Communities: Who is Speaking, and Who is Listening to the Women? Using an Ethics of Care to Promote Diverse Voices. *Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency*, 106–115. https://doi.org/10.1145/3442188.3445874

Galpin, V. *Women in Computing around the World: An Initial Comparison of International Statistics.*

Harrison, R. L., Drenten, J., & Pendarvis, N. (2016). Gamer Girls: Navigating a Subculture of Gender Inequality. In N. Özçağlar-Toulouse, D. Rinallo, & R. W. Belk (Eds.), *Research in Consumer Behavior* (Vol. 18, pp. 47–64). Emerald Group Publishing Limited. https://doi.org/10.1108/S0885-211120160000018004

Ko, A. J., & Davis, K. (2017). Computing Mentorship in a Software Boomtown: Relationships to Adolescent Interest and Beliefs. *Proceedings of the 2017 ACM Conference on International Computing Education Research*, 236–244. https://doi.org/10.1145/3105726.3106177

Kordaki, M., Berdousis, I. University of the Aegean, (2020). Identifying barriers for women participation in computer science. Pro Edu. *International Journal of Educational Sciences*, 2(2), 5–20. https://doi.org/10.26520/peijes.2020.2.2.5-20

LaBerge, N., Wapman, K. H., Morgan, A. C., Zhang, S., Larremore, D. B., & Clauset, A. (2022). Subfield prestige and gender inequality in computing (arXiv:2201.00254). arXiv. http://arxiv.org/abs/2201.00254

Lehman, K. J., Sax, L. J., & Zimmerman, H. B. (2016). Women planning to major in computer science: Who are they and what makes them unique? *Computer Science Education*, 26(4), 277–298. https://doi.org/10.1080/08993408.2016.1271536

Leonard, D. (2003). Live in your world, play in ours: Race, video games, and consuming the

      other. *Studies in media & information literacy education*, *3*(4), 1-9.

Maalouf, T. (2019). Trends in Women's Participation in Computer Industry Subfields. *The*

      Kabod, *5*(2).

Master, A., Meltzoff, A. N., & Cheryan, S. (2021). Gender stereotypes about interests start early

      and cause gender disparities in computer science and engineering. *Proceedings of the*

      National Academy of Sciences, *118*(48), e2100030118.

      https://doi.org/10.1073/pnas.2100030118

Renner, B. (2019, April 27). *Study: Playing video games puts young girls at risk of isolation,*

      delayed social skills. Study Finds. https://studyfinds.org/playing-video-games-young-

      girls-isolation-delayed-social-skills/

Rivera, H. *Average College Graduate Salaries*. Bankrate. Retrieved May 2, 2023, from

      https://www.bankrate.com/loans/student-loans/average-college-graduate-salary/

Seo, E., & Lee, Y. K. (2021). Stereotype Threat in High School Classrooms: How It Links to

      Teacher Mindset Climate, Mathematics Anxiety, and Achievement. *Journal of youth and*

      adolescence, *50*(7), 1410–1423. https://doi.org/10.1007/s10964-021-01435-x

Smith, D. G., & Schonfeld, N. B. (2000). The Benefits of Diversity what the Research Tells Us.

      About Campus, 5(5), 16–23. https://doi.org/10.1177/108648220000500505

Spieler, B., Oates-Indruchovà, L., & Slany, W. (2020). Female students in computer science

      education: understanding stereotypes, negative impacts, and positive motivation. *Journal*

of Women and Minorities in Science and Engineering, 26(5), 473–510.

https://doi.org/10.1615/JWomenMinorScienEng.2020028567

SurveyTandem | Find survey participants & respondents for free. Retrieved April 5, 2023, from

https://www.surveytandem.com/#/

Warner, S. L. (1965). Randomized Response: A Survey Technique for Eliminating Evasive

Answer Bias. *Journal of the American Statistical Association*, *60*(309), 63–69.

https://doi.org/10.1080/01621459.1965.10480775

Appendix

Questionnaire:

1. How do you identify?

   - Male

   - Female

   - Nonbinary

   - Other/prefer not to say

2. How old are you?

3. What do you know about computer science?

4. Do you have any experience with computer science?

   - I have taken a course
   - I taught myself some things
   - I have participated in projects/programs
   - No experience

5. Do you have an interest in learning more about computer science? (yes/no)

6. Are you able to take a computer science course if you want to? (yes/no)

7. Do you have peers involved with computer science? (yes/no)

8. What is the most important factor to you when selecting a career?

   - maintaining a healthy work-life balance
   - making a positive social difference in the world
   - earning a high salary

9. What other factors are important to you when selecting a career?

10. Would you consider a career in computer science? (yes/no)