The Culture of Computer Science, A Short Review of Literature

Abstract

Popular media and academic literature are rife with statistical descriptions of "underrepresentation" in computer science education and careers. Because of this, there is an increasing amount of research on what can be done in the classroom and in extra-curricular activities to attract women and students of color. A related effort is attempting to close the so-called "leaky pipeline" in which students lose their interest in computer science and pursue other subjects in high school or college. This literature review advances the idea that in order to treat these symptoms, the underlying cause must be addressed: the culture of computer science.

Introduction

"Culture" is a difficult word to define, especially with regards to a world-wide subject affecting people of all ages and backgrounds. If we use a set of values, traditions and practices loosley agreed upon, generally shared, and tightly linked to personal identity, and frame it in the context of the history of computer science (including media portrayals),we see how the culture of computer science has been based on the stereotype of the computer scientist as a socially-awkward white male (Master et al., 2016). The corollary is that young women and students of color do not see themselves in computer science classes or careers (Lewis et al., 2019). Students who see no values in common with the stereotypes of a different culture will not only have little motivation to explore that culture, they experience a heavy social price for expressing any kind of interest at all (Tatum, 2017). While the moral imperative of representation in computer science is established at length elsewhere (bobb 2021, Lewis et al., 2017, 2019) this paper will argue that in order to attract and retain women and students of color, the entire culture of computer science must change. The question is "how?"

Computer Science Culture and History

In recent years, there has been a great increase in the interest of women in computer science from popular books and movies such as “Hidden Figures” to extra-curricular activities such as Technovation, Girls Who Code, and the National Center for Women in IT. However, as recently as a decade ago, all of the most well-known computer scientists were white males, simply because all of the history books were written by white males (Master et al., 2016). Bill Gates, Steve Jobs and Mark Zuckerberg were probably the only famous computer scientists that came to mind, and all three fit the stereotype. Despite the fact that women have been integral to computer science since the first computing machines were invented in the 1840’s, it has taken a huge effort by thousands of people to recognize and honor the contributions of women and people of color in computer science such as Ada Lovelace, Grace Hopper and Katherine Johnson, and to bring their names to the forefront of popular knowledge. Notwithstanding this achievement, it is only the first step in changing the culture in computer science - updating the narrative to include and recognize all the participants. Despite the changes in the past decade, women and people of color who are successful in tech careers are still seen as outliers (Masters et al., 2016, Lewis et al., 2019, Rankin et al., 2019). The white male stereotype remains and has an overwhelming impact on the makeup of computer science in schools and the workforce. Not only are these groups excluded from some of the highest-paying and high-status careers, computer science itself is crippled by its lack of diverse perspectives that could lead to new advancements and better products.

Perception of Computer Science

Computer science is generally perceived as an intellectual pursuit. Many students believe that it requires “brilliance”, that it leads to a lonely life of programming, and has no relation to communal goals such as helping or working with others (Diekman et al., 2010). This

assumption of brilliance or a “geek gene” (Lewis et al. 2011) relates closely to other historic narratives about intelligence - which groups of people have it and which ones don’t. There is a long pattern of claims throughout history that women and people of color have inferior intellects (Kendi 2016) and this obviously has an effect on who sees themselves and others in intellectual fields (Bergman 2002). These stereotypes can also be reinforced by the environment in which students learn. Stereotype threat and the perception of “not belonging” is significant for high school women and students of color. When women and students of color enter the computer science space, they tend to believe they will be judged negatively from the outset (Master et al., 2016). Stereotypical environments which celebrate the historic narrative of computing such as famous white males, images from science-fiction, video games, tech magazines, computer parts, and individualized work spaces reinforce the stereotype threat in students who do not see those elements in their own culture. A non-stereotypical environment without these items and which includes group workspaces, lamps, plants, and nature and art posters does not change interest in computer science for white males, but significantly increases it for all other groups (Master et al., 2016).

Compounding the issues of perception of ability and learning environment are the conscious and unconscious biases of educators and parents. Although there is no evidence to support the idea of an “innate ability for computing”, the belief persists among teachers and the population at large (Robins, 2010). White boys are far more likely to be told that they could be “good at CS” by both teachers and parents than any other dis-aggregated group. Students who are encouraged are 2.5 times more likely to take at least one elective course in CS at some point in high school or college (Google Inc. and Gallup Inc., 2017). Although students of any race or gender who had prior computer experience were seen by teachers as having a greater “innate” ability, the fact that young white boys are far more likely to have had access to some kind of computer training constantly reinforces teachers’ gender and race biases (Master et al., 2016).

This is why early access is listed as one of the highest predictors of continuing interest in computer science. The implicit and explicit bias around "innate ability" has profound and lasting consequences on the makeup computer science classes, whether in elementary school or the first years of college. The combination of early access reinforced by parents' and teachers' initial support puts young white males at a huge advantage over their peers. The culture *surrounding* computer science changes its demographics before students even begin.

Unfortunately, the lack of positive reinforcement is not the only effect from influencing adults. Despite a preponderance of evidence of sexism and racism in society, teachers still tend to dismiss complaints in their own classrooms as "exaggerated" or "all in the [student's] head". Because these topics are socially awkward to discuss, students will talk about racism and sexism in class among themselves, but will rarely bring it up with a teacher or professor (Lewis et al., 2016). If we are to improve the culture of computer science classes, it is imperative that teachers not only take students' claims of sexism or racism seriously, teachers must proactively discuss and address sexism and racism in their own classrooms.

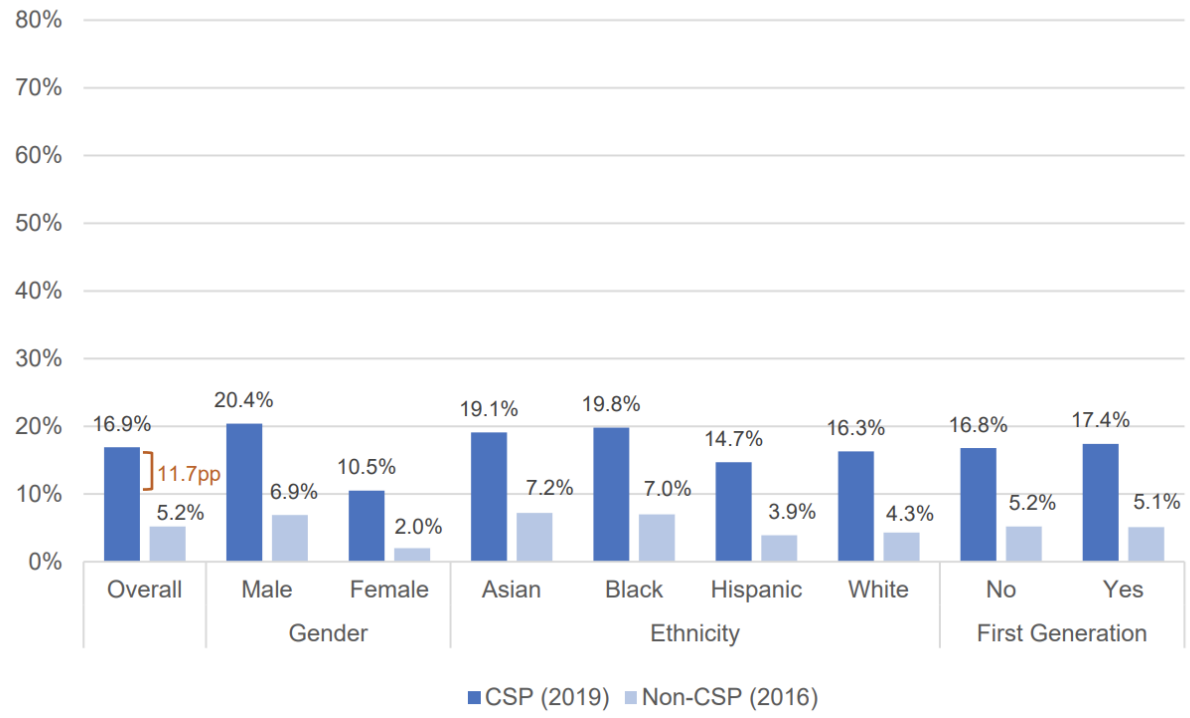
In addition to pressure from teachers, parents, and peers, students themselves often do not see how computer science aligns with their value systems. Women, students of color, and first-generation college students tend to hold strong communal goals, defined as the desire to serve humanity and work for the betterment of others (Lewis et al., 2019). This is in contrast to agentic goals that relate to the desire for achievement, independence, and self-promotion. Computer science is seen as offering less emphasis on community and more on agency as opposed to other pathways such as social sciences or life sciences. In fact, for those who are already in computer science pathways, communal goal orientations are negatively correlated with a "sense of belonging" and positively correlated with leaving for another field (Lewis et al, 2019). This is a purely subjective, cultural phenomenon. There is no reason that computer

science could not be more balanced, except for the fact that those designing the curricula were successful in the existing system and those who are in positions of power tend to propagate the systems in which they achieved their success (bobb 2021).

Changing the Culture of Computer Science

Some measures are being made to change the culture of computer science, such as the new AP Computer Science Principles (CSP) course, which uses research-based attempts to emphasize creativity, group activity, and creating products which target community activism. Thirty percent more females take AP CSP versus the standard AP Computer Science exam. Twice as many black students and almost twice as many first-generation students take AP CSP vs AP CSA (Wyatt et al., 2020). These results may be small, but are significant. To illustrate this, the difference in retention rates in computer science between those who take AP CSP - a class which attempts to challenge the historic culture of CS - and those who do not take it are striking:

Figure 1: The Percentage of CSP and Non-CSP Students Who Major in CS



Note: This sample includes 36,848 students, 18,424 each of CSP and non-CSP students who are matched on academic performance and background characteristics. The non-CSP students graduated in 2016 while the CSP graduated in 2019, with all students enrolling in a four-year college and declared a major. The CSP students attended a high school that offered CSP continuously from 2017 through 2019. All differences between the CSP students and the non-CSP students are significant at the .05 level. PP represents percentage point.

Across every group shown in Figure 1, the number of students who felt they belonged enough in computer science to declare it as their major in college at least tripled, and the increase was greatest for females and black and hispanic students. This clearly shows that when students see their own cultural values reflected in the computer science curriculum, they are much more likely to feel like they belong in computer science, and are much more likely to continue studying the subject over the long term.

Recommendations

First and foremost, early access is vital to success in computer science. When students become interested at an early age, before the social pressures of middle and high school take hold, they are more likely to feel confident in a subject and to be encouraged by teachers and parents (Robins, 2010). That being said, access alone is not enough. Equitable education requires access to rich course content, to quality instruction, to achievable identities as computer scientists, and to supportive peer and advisor relationships (Shah et al., 2013). Rich course content and quality instruction must include authentic experiences that validate and incorporate the experiences and cultural norms outside of the stereotypical white, male culture. Teachers and practitioners must recognize that computer science (and all education) exists within a racial construct, a gender construct, a sexuality construct, and further intersections thereof. Teachers and practitioners must receive training throughout their careers and work throughout their careers to understand, support, and explicitly discuss issues around race,

gender, and sexuality as they pertain to the class and school itself, and as they pertain to computer science and its effect in the world.

Conclusion

There are many factors affecting the culture of computer science, and most of them are implicitly or explicitly biased against women, students of color, and first-generation college students. From the compound effects of early access to the societal pressure of fitting in with stereotypes, young women and students of color are at a huge disadvantage when it comes to computer science education and careers. It will take a concerted effort from schools, educators, curriculum designers, parents, and students in concert to build communities of trust where all students feel that they belong. As demonstrated throughout this paper, that feeling of belonging is the strongest factor in a student's longevity in computer science. It will require changes in curricula, pedagogy, environment, and more. The bottom line is that we cannot wait for more women and students of color to change the culture in computer science. It is up to the current teachers and practitioners to do the work to change computer science now so that it represents the interests and values of the student body at large. As Gloria Ladson-Billings said, "It's up to white teachers to recognize whiteness in the classrooms". The research towards achieving these changes in culture is just beginning across all STEM fields and the results so far are promising. While the status quo may look bleak, if we can use the momentum and research to continuously improve, the future looks very bright indeed.

Citations

Bergman G. The history of the human female inferiority ideas in evolutionary biology. Riv Biol. 2002 Sep-Dec;95(3):379-412. PMID: 12680306.

bobb, kamau. (2021). *CS Education at an American Inflection* [Video]. CSTA Leadership Conference - Equity in Computer Science series. https://www.youtube.com/watch?v=I5NIOJeDL9g&t=8s

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science*, 21,1051–1057. http://dx.doi.org/10.1177/0956797610377342

Google Inc, & Gallup Inc. (2019). *Encouraging Students Toward Computer Science Learning. Results From the 2015–2016 Google–Gallup Study of Computer Science in U.S. K–12 Schools (Issue Brief No. 5)*. Google Inc. https://goo.gl/iM5g3A

Kendi, I. X. (2017). *Stamped from the beginning the definitive history of racist ideas in America*. Bold Type Books.

Lewis, C., Bruno, P., Raygoza, J., & Wang, J. (2019). Alignment of Goals and Perceptions of Computing PredictsStudents' Sense of Belonging in Computing. *Proceedings of the International Computer Science Education Research Workshop*. Toronto, Canada

Lewis, C. M., Shah, N., & Falkner, K. (2019). Equity and diversity. In S. Fincher & A. Robins, *The Cambridge Handbook of Computing Education Research*. Cambridge University Press.

Master, A., Cheryan, S., & Meltzoff, A. (2016). Computing Whether She Belongs: Stereotypes Undermine Girls' Interestand Sense of Belonging in Computer Science. *Journal of Educational Psychology*, *108*(3), 424–437.

Rankin, Y. A., Thomas, J. O., & Irish, I. (2019). Food for Thought: Supporting African American Women's Computational Algorithmic Thinking in an Intro CS Course.

SIGCSE '19: Proceedings of the 50th ACM Technical Symposium on Computer Science Education, 641–646.

Shah, N., Lewis, C., Caires, R., Khan, N., Qureshi, A., Ehsanipour, D., & Gupta, N. (2013). Building Equitable Computer Science Classrooms: Elements of a Teaching Approach. *ACM SIGCSE Bulletin*, *44(1)*, 263–268.

Tatum, B. D. (2017). *"Why are all the black kids sitting together in the cafeteria?": And other conversations about race* (Third trade paperback edition). Basic Books.

Wyatt, J., Feng, J., & Ewing, M. (2020). *AP Computer Science Principles and the STEM and Computer Science Pipelines*. The College Board. https://apcentral.collegeboard.org/pdf/ap-csp-and-stem-cs-pipelines.pdf?course=ap-computer-science-principles