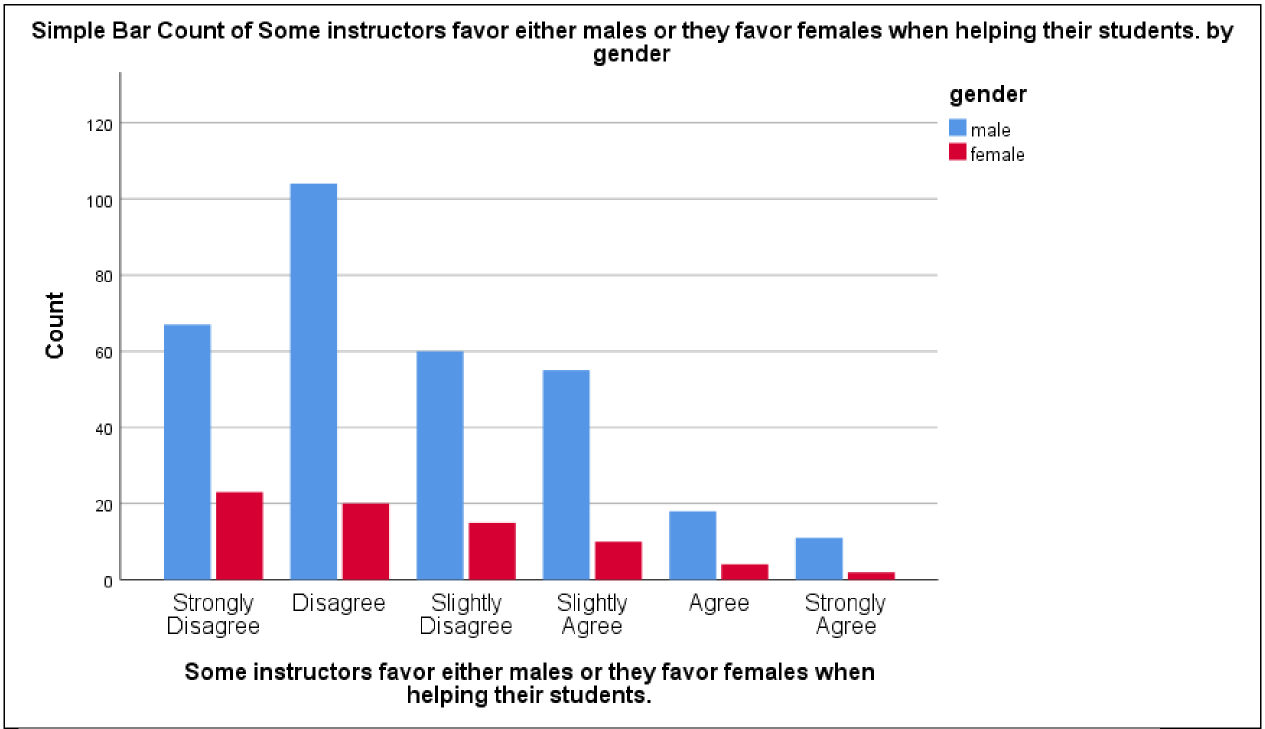
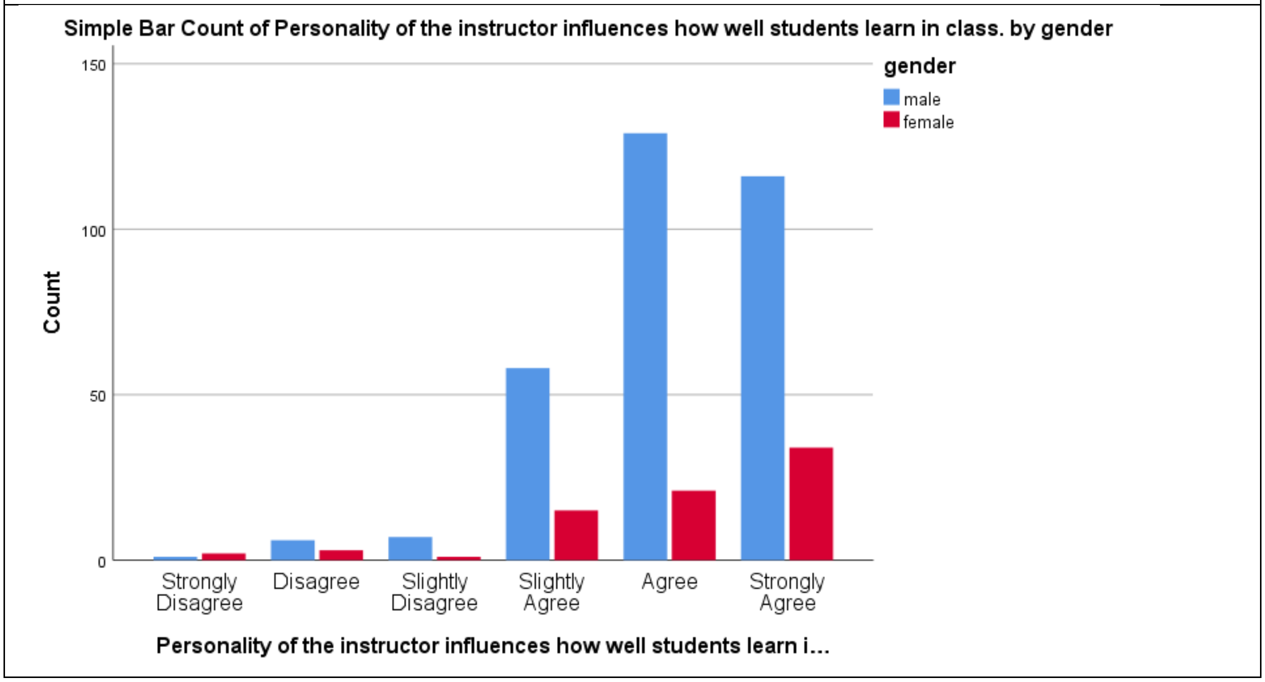
Identifying gender differences in undergraduate Computer Science students: Women aren't so different

Dr. Carl Siebert(A), Kathleen Mullen(A), Dr. Noah Salzman(B)
Boise State University, (A) Dept. of Curriculum Instruction and Foundational Studies (B) Dept. of Electrical & Computer Engineering

National Science Foundation (NSF)
(IUSE/RED - 6PRJ000899 & 6PRJ000914)





Abstract

STEM employment is growing at twice the rate of other occupations, with computer-related fields demonstrating the greatest growth. Yet, as the need for talent grows, the proportion of computer-related baccalaureates awarded to women declined from 28% in 2000 to 18% in 2013. As part of an NSF-sponsored project, we examined gender differences as a first step to explaining the low numbers of female Computer Science (CS) graduates. Our survey of 393 CS undergraduates found no significant differences in psychological traits like self-esteem and self-efficacy, but more women reported high stress. Data pointed to possible differences only in student-faculty engagement. Future work will investigate why CS is losing or not attracting talented women.

Background

Continued development of the science, technology, engineering, and mathematics (STEM) workforce is critical to U.S. competitiveness in a global economy increasingly driven by technological innovation (U.S. Government Accountability Office, 2014). The importance of this sector is reflected in occupational and wage trends, with STEM employment growing at twice the rate of other occupational areas (10.5% vs. 5.2%) and offering wages nearly double the non-STEM average (Fayer, Lacey, & Watson, 2017). Within STEM, computer-related fields demonstrate the greatest growth and are expected to generate nearly half a million new jobs by 2024.

Yet, as the need for talent grows, women represent a minority in computing professions and have become less likely to complete computing-related undergraduate degrees such as Computer Science, Computer Engineering, or Information Technology (Bureau of Labor Statistics; U.S. Departmment of Labor, 2016; National Science Foundation and the National Center for Science and Engineering Statistics, 2017). Female undergraduates plan to major in Computer Science at lower rates than their male peers and are more likely to leave the major before receiving a degree (Babe-Vroman et al., 2017; National Science Board, 2016). Low completion levels are seen in the proportion of computing-related baccalaureates awarded to women, which declined from 28 percent in 2000 to just 18 percent in 2013. STEM education and training pathways vary but skills often advance through participation in postsecondary programs (National Science Board, 2015). The knowledge and abilities developed through baccalaureate studies thus represent an important factor in the development of a highly skilled workforce. The underrepresentation of women therefore limits talent development in one of the economy's fastest growing sectors.

As highlighted in several meta-analyses and reviews, researchers seeking to better understand gender disparities in educational and occupational outcomes for STEM fields have focused on a range of anticipated factors, from biological differences to sociocultural influences believed to affect men and women's performance differently (Ceci, Williams, & Barnett, 2009; Cohoon & Aspray, 2006; Hill, Corbett, & St. Rose, 2010; Singh, Allen, Scheckler, & Darlington, 2007). These reviews collectively find that social and cultural environments exert a strong influence on how women develop their interests and work toward their goals. For undergraduate women, feeling that professors did not take them seriously (Sax, 2009), that performance reviews favored males (Steele, James, & Barnett, 2002; Thoman & Sansone, 2016), that Computer Science departments privileged male "geek" norms (Margolis & Fisher, 2002), and that the learning environment was impersonal (Beyer, DeKeuster, Walter, Colar, & Holcomb, 2005) all negatively impacted academic aspirations. Female undergraduates also generally reported lower levels of self-esteem than their male peers (Sprecher, Brooks, & Avogo, 2013), often enter college with less computer experience, are less confident in both their personal computer skills and their ability to teach others, and anticipate difficulty balancing family and career in Computer Science (Beyer et al., 2005).

One effort to address the need to increase the number of women in STEM comes from the federal government. The National Science Foundation (NSF) has funded multiple 5-year projects to revolutionize engineering and Computer Science departments throughout the U.S. (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505105). The NSF program (NSF 15-607 IUSE/RED) is aligned with the very large effort to improve undergraduate STEM education. Our current study is embedded in one of the funded projects that intends to enact sustainable changes in undergraduate Computer Science education by replicating best work practices in software companies while focusing on cultural competency and social justice. Our study contributes to the cultural competency and social justice goals.

Purpose

The purpose of this study is to investigate reported gender differences for undergraduate students involved in Computer Science education, thereby identifying opportunities to improve the educational experience for undergraduate students, especially for women.

Method

We developed an online questionnaire to gather information on beliefs and experiences from undergraduate students who identify as Computer Science majors, minors, or are currently taking Computer Science classes. We invited undergraduate students from a northwest university (N=1168) to complete this questionnaire. Five rounds of email invitations were sent over a 35-day period, resulting in 522 responses (44.7% response rate). The data were cleaned and reviewed for reliability and validity, and 403 provided usable responses to survey questions and answered the sexual identity question necessary for this study. Due to the small number of responses to some of the sexual identity options, only male (N=317) and female (N=76) responders were included in the study, 80.7% and 19.3% respectively.

Respondents answered multiple demographic questions (e.g., age, program year, employment, race/ethnicity, major, and number of college credits completed and currently taking). Among the respondents, 81.4% identified as CS major/minor, and less than 3% identified as non-STEM. The sample was made up of 13.7% first-year students, 21.1% Sophomores, 22.6% Juniors, and 28% Seniors. Students were young; 25.7% were 20 years old or younger, 33.3% were 21-24 years old, 21.6% were 25-30 years old, and 19.2% were 31+ years old. In terms of ethnicity and race, 9.9% identified as Hispanic or Latino, 8.4% identified as only Asian, 79.6% as only White, and 1.3% as only Black or African American.

In addition to demographic questions, we asked respondents multiple questions about the degree to which Computer Science courses were preparing them effectively for employment (e.g., *I believe the current list of Computer Science classes will prepare me for successful employment*, *I believe the class content taught in the Computer Science department matches what employers are looking for in new hire candidates*), along with items about the effectiveness of the teachers (e.g., *In general, the teachers/professors are able to teach effectively the content taught in Computer Science classes*). More importantly, questions related to unequal treatment or perceived bias for males or females in the curriculum were included (e.g., *Some content taught in class is better understood by males than by females*, *Race/ethnicity of the instructor influences how well students learn in class*). Items about teacher behavior/treatment and favoritism were presented, (e.g., *I feel I am able to communicate with my teachers/professors whenever I want*), in addition to questions about the behavior, treatment, and favoritism of other students (e.g., *I find it easier to work in a team where everyone is the same race than when the team is more diverse*, *Minority students have an easier time finding work after graduation than other students*). In addition, respondents were asked to complete validated scales on self-efficacy (Schwarzer & Jerusalem, 1995), self-esteem (Rosenberg, 1965), perceived stress (Cohen, Kamarck, & Memelstein, 1983), and resistance to change (Oreg, 2003). Overall, the questionnaire included 90 quantitative and qualitative questions covering a wide range of beliefs and experiences. We hypothesized that we would find statistically significant gender differences in all these areas.

The online questionnaire was created in Qualtrics (Qualtrics, Provo, UT) and executed using Qualtrics's notification and data collection capabilities. After the survey, we exported the data to SPSS 24 (IBM Corp., 2016). Once exported, the data were cleaned, verified, and closely examined for missing bias. Each variable was analyzed individually to make sure the necessary variations in responses within the quantitative questions supported the use of the variable in further analyses. Next, the four validated scales were tested for their level of reliability (Cronbach's Alpha) for this sample. Self-efficacy (α=.86), self-esteem (α=.89), perceived stress (α=.85), and resistance to change (α=.82) all demonstrated solid reliability.

In addition to the univariate analysis conducted on all the variables and verifying the usability of validated scales, an examination for possible differences between responders who did and did not answer the sexual identity question was conducted. Visual comparison of response distributions, t-tests, and ANOVA were used in this examination.

Findings

The examination of possible differences related to respondents who did and did not respond to the sexual identity question found no evidence, either statistically or visually, of any responder bias. Therefore, the study proceeded to look for reported gender differences. Although our hypothesis was that statistically significant gender differences would be present for beliefs and experiences about the quality of CS courses, engagement among students, preparation for employment, cultural cohesiveness, and teacher/instructor interaction, none of these questions demonstrated statistically significant gender differences.

One possible explanation for this finding could be the small proportion of females to males and the possible small effect size. Using G*Power (Erdfelder, Faul, & Buchner, 1996), a post-hoc power analysis for achieved effect size (power=.8, alpha=.05, sample sizes of 317 males and 76 females) is 0.36, suggesting that a moderate effect size would be needed to achieve significance. However, visual examinations of response distributions show two possible differences in responses between males and females. The first is for the question *Personality of the instructor influences how well students learn in class* and the other is *Some instructors favor either males or they favor females when helping their students*. Despite the variety of topics included in our analyses, the only items visually identified as having male/female differences are about instructors, suggesting that student-to-instructor engagement may play a larger role in gender educational experiences than other possible issues (e.g., peer interactions, course/class content).

The analyses of gender differences for the four validated scales also demonstrated no statistically significant differences. Due to the non-normal distributions for self-esteem and self-efficacy, both the independent-sample t-test and a set of nonparametric procedures (Mann-Whitney U, Kolmogorov-Smirnov, Wald-Wolfowitz, and Moses extreme reaction) were conducted on all four measures. None of these tests found significance at α=.05 for gender differences. However, per Rosenberg's Self-Esteem scale, scores below 15 suggest low self-esteem. Using that guideline for our respondents indicates that 44 students (11.4%) fall into the low self-esteem category. Of the 44 students, 37 males (or 11.7% of all males) and 7 females (or 9.2% of all females) report low self-esteem, illustrating that this is not a gendered issue, but an overall student issue. In addition, scores on the Perceived Stress Scale of 20 or higher are considered as high stress. Importantly, 93 (29.3%) of males and 40 (39.5%) of females fall into the high stress category, indicating that percentage of stressed individuals by gender is recognizably, if not statistically, higher in female students.

Conclusion

These findings suggest that engagement with professors/instructors may be different for male and female students in CS education. In our study, a larger proportion of women than men report that professors/instructors favor either males or females, and that professor/instructor personality influences how well students learn. In addition, the percentages of highly-stressed individuals suggest that more females than males are dealing with high stress during their undergraduate education. We do not currently know the reason for the high stress, or if it is the cause for the many women who leave the study of CS in their junior year. Nevertheless, the quantitative findings extend the commonplace belief that women are somehow inherently different when it comes to important characteristics like self-efficacy and self-esteem. Our findings suggest that they share these same attributes with their male colleagues, thus eliminating these kinds of psychological fortitude issues as reasons for their attrition from CS programs. However, these results do suggest that the environment needs some adjustments so that women can remain and succeed in CS programs. Of course, recruitment is an issue as well, and we hope that the second stage of our study will shed some light on recruitment as well as retention. We hope to discover why women experience professor/instructor engagement differently and the reason they appear to experience more stress by analyzing the responses to multiple qualitative questions within our survey. We may be able to report on some of the highlights of these analyses in our AERA presentation, but we are in the first year of a 5-year evaluation that promises to provide useful data for upcoming years. The rate of increase in job opportunities for CS graduates shows no signs of slowing down, which means it is imperative for every CS program to address issues of gender bias. Otherwise, the number of highly skilled and talented women seeking CS career opportunities will not keep pace, thereby placing us in a serious disadvantage in the growth of Computer Science and technology.

References

Babe-Vroman, M., Juniewicz, I., Lucarelli, B., Fox, N., Nguyen, T., & Tjang, A. (2017). Exploring gender diversity in CS at a large public R1 research university. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education* (pp. 51–56). Seattle, WA. http://doi.org/10.1145/3017680.3017773

Beyer, S., DeKeuster, M., Walter, K., Colar, M., & Holcomb, C. (2005). Changes in CS students' attitudes towards CS over time: An examination of gender differences. In *Proceedings of the 2005 Conference on Integrating Technology into Computer Science Education, ITiCSE* (pp. 392–396). St. Louis, MO. https://doi.org/10.1145/1047124.1047475

Bureau of Labor Statistics; U.S. Departmment of Labor. (2016). *Employed persons by detailed occupation, sex, race, and Hispanic or Latino ethnicity*. *Labor force statistics from the Current Population Survey*. Retrieved from http://www.bls.gov/cps/cpsaat11.htm

Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's underrepresentation in science: Sociocultural and biological considerations. *Psychological Bulletin*, *135*(2), 218–261. http://doi.org/10.1037/a0014412

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 24, 4, 385-396. http://dx.doi.org/10.2307/2136404

Cohoon, J. M., & Aspray, W. (2006). *Women and information technology: Research on underrepresentation*. Cambridge, Mass.: MIT Press.

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers*, 28, 1-11.

Fayer, S., Lacey, A., & Watson, A. (2017). *STEM occupations: Past, present, and future*. Retrieved from https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few?: Women in science, technology, engineering, and mathematics*. Washington, D.C.: AAUW. Retrieved from https://www.aauw.org/files/2013/02/Why-So-Few-Women-in-Science-Technology-Engineering-and-Mathematics.pdf

IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

Margolis, J., & Fisher, A. (2002). *Unlocking the clubhouse: Women in computing.* Cambridge, Mass.: MIT Press.

National Science Board. (2015). *Revisiting the STEM workforce: A companion to science and engineering* *indicators 2014*. Arlington, VA. Retrieved from https://www.nsf.gov/nsb/publications/2015/nsb201510.pdf

National Science Board. (2016). *Higher education in science and engineering. Science and engineering indicators 2016*. Arlington, VA. Retrieved from http://www.nsf.gov/statistics/seind16/

National Science Foundation and the National Center for Science and Engineering Statistics. (2017). *Women, minorities, and persons with disabilities in science and engineering: 2017. Special Report NSF 17-310*. Retrieved from https://www.nsf.gov/statistics/2017/nsf17310/static/downloads/nsf17310-digest.pdf%5Cnhttp://www.nsf.gov/statistics/wmpd

Oreg, S. (2003). Resistance to change: Developing an individual differences measure. *Journal of Applied Psychology*, 88(4), 680-693. doi:10.1037/0021-9010.88.4.680

Rosenberg, M. (1965). *Society and the adolescent self-image*. Princeton, NJ: Princeton University Press.

Sax, L. J. (2009). Gender matters: The variable effect of gender on the student experience. *About Campus*, (June), 2–10. http://doi.org/10.1002/abc.283

Schwarzer, R., & Jerusalem, M. (1995). Generalized Self-Efficacy scale. In J. Weinman, S. Wright, & M. Johnston, *Measures in health psychology: A user's portfolio.* Causal and control beliefs, 35-37, Windsor, England: MFER-NELSON.

Singh, K., Allen, K. R., Scheckler, R., & Darlington, L. (2007). Women in computer-related Majors: A critical synthesis of research and theory from 1994 to 2005. *Review of Educational Research*, *77*(4), 500–533. Retrieved from http://www.jstor.org/stable/4624909

Sprecher, S., Brooks, J. E., & Avogo, W. (2013). Self-esteem among young adults: Differences and similarities based on gender, race, and cohort (1990-2012). *Sex Roles*, *69*, 264. http://doi.org/10.1007/s11199-013-0295-y

Steele, J., James, J. B., & Barnett, R. C. (2002). Learning in a man's world: Examining the perceptions of undergraduate women in male-dominated academic areas. *Psychology of Women Quarterly*, *26*(1), 46–50. http://doi.org/10.1111/1471-6402.00042

Thoman, D. B., & Sansone, C. (2016). Gender bias triggers diverging science interests between women and men: The role of activity interest appraisals. *Motivation and Emotion*, *40*(3), 464–477. http://doi.org/10.1007/s11031-016-9550-1

U.S. Government Accountability Office. (2014). *Science, technology, engineering, and mathematics education: Assessing the relationship between education and the workforce*. Retrieved from http://www.gao.gov/assets/670/663079.pdf