



Obstacles to Women in Computing: Re-Examining the Literature in 2020

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Authors' contributions

This work was carried out collaboratively by both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This report examines the ongoing gender divide in computing and, in particular, the determinants and distractors that influence women's decisions to study and pursue careers in technology. Numerous research studies have explored this divide in the past, and many of the findings are routinely cited in the literature. However, most of this research was conducted some years ago. Technology is a field that changes rapidly, and societal understanding and embracement of computers and technology have also evolved. This paper reports on a longitudinal study that seeks to measure changes in perceptions over time and determine whether or not prior barriers are as impactful as they might have been.

Keywords: Female role models; computing; technical careers.

1. INTRODUCTION

In August 2017, Google publicly fired a software engineer who had authored an internal memo that questioned its efforts to promote diversity, particularly concerning women in technical

positions. The memo's author argued that much of the reason for low female representation in technical careers is a personal choice, resulting from inherent differences between men and women, not because of widespread sexism and discrimination in the industry. The story reignited

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the conversation about why there is such a significant imbalance in the computer industry and why women are so much less likely than men to choose to study technology in college and pursue careers in the field [1].

Today, at \$1.9 trillion in economic output, the technology sector accounts for approximately 10% of the U.S. economy and employs an estimated 12.1 million workers. As a result of this growth in technology, computing majors' popularity has been strong for many decades, with forecasts for continued growth in the future [2]. In 2019, there were an estimated 4.6 million postings for tech occupations in the U.S. The median wage for those employed in computing professions is nearly twice the national median [3].

Despite this, one persistent trend has been the steady decline of females choosing to pursue computing careers in the U.S. [4]. Fig. 1 shows the enrollment in computing programs of study in recent years. Computer Science was one of the fastest-growing programs of study among women during the 1970s and early 1980s. At the enrollment peak of 1986, women earned approximately 37% of the bachelor's degrees

awarded in the U.S. Since then, the number and percentage have gradually declined – falling to 30% in 1991 and 18% in 2014 [5].

The trend is not limited to college enrollments but includes employment in the technology sector as well. In the 1980s, women held 38% of the computing workforce positions, but have steadily declined since then [6,5] observes that the computing industry's job creation rate in the U.S. is three times higher than the national average. However, if current trends continue, estimates are that women will occupy less than 20% of computing jobs by 2025.

The phenomenon of declining female participation in technology careers is not universal and is more problematic in western countries than in other parts of the world (Schinzel, 2017). In contrast, female students in India make up 45% of the enrollment in computing majors, almost three times the amount seen in the U.S. [7]. In 2015, the majority of internet business startups in China were headed by women. In Saudi Arabian universities, females make up nearly 60% of the students enrolled in computer science [8].

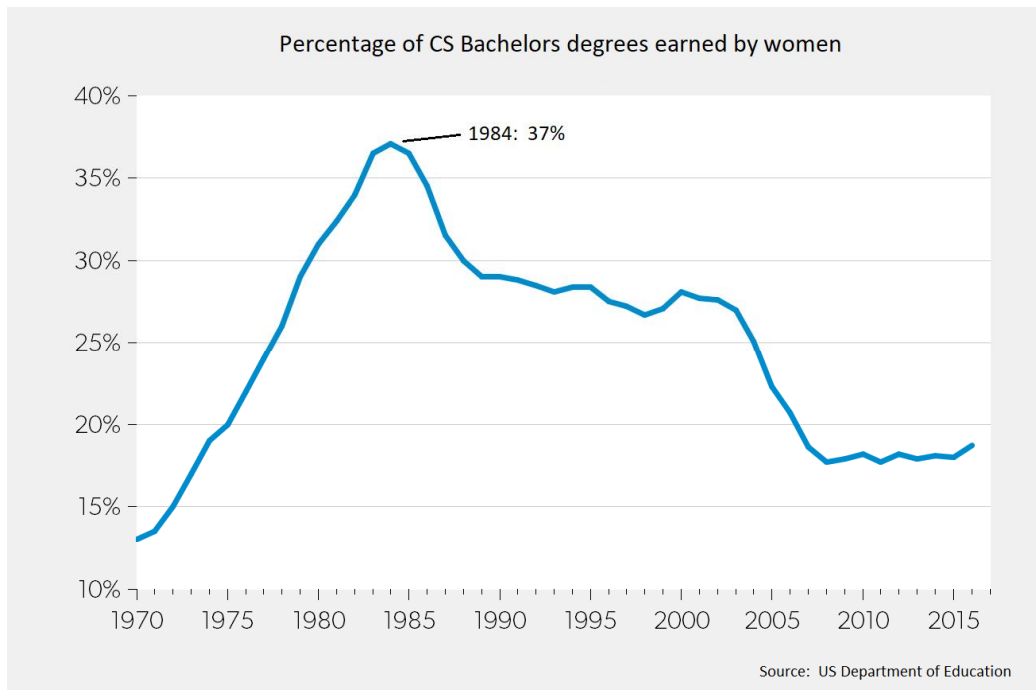


Fig. 1. Percentage of bachelor's degrees in computer science earned by women

Numerous studies have examined the issue, and prescriptive recommendations have been made. Despite this research and various industry and educational efforts to reduce the disparity, the trend continues [9]. Many of the frequently cited studies were conducted some years ago (e.g. Jagacinski et al., 1988;) [4,10,11,12]. Technology tends to change quickly, as does society's acceptance of it. Although the gender divide still exists, are the underlying reasons for females choosing other academic options still consistent with prior research findings? In this study, we explore and contrast changes over the past two decades and seek to understand if the established assumptions about female participation in computing are still valid today.

2. BACKGROUND

Female participation in the computing sciences goes as far back as the computer itself. Prior to the invention of electronic computers, the term *computer* referred to a mathematically skilled human who could perform complex numeric calculations. Human computers were employed by universities, government agencies, and engineering businesses. By the beginning of World War II, the majority of human computers were women. The first programmable electronic computer, the ENIAC, was programmed and operated by a team of mostly female scientists. The computer was developed as part of the war efforts in 1945, and labor shortages led to women taking on many roles that had historically been occupied by men [13]. This trend continued after the war and women continued to work as programmers and computer operators.

Through the 1960s and into the 1970s, female professionals continued to be heavily involved in programming computers [14]. During this period, men tended to focus on computing hardware development while women worked on software. With the development of the personal computer and the associated shift away from larger mainframe machines, the accelerated growth of applications and software became more critical. This shift correlated with the increase in male participation in computing occupations and women's decrease [15].

Various researchers have studied the dramatic decline in female participation in computing (e.g., Camp, 1997; Margolis & Fisher, 2002; Vesgo, 2005; Pollacia & Lomerson, 2006) [4,16,17,18]. These studies have identified several different issues that contribute to declines in female

participation and have offered prescriptive suggestions on how the problem might be overcome. The research findings suggest that the lack of interest by female students is likely due to one or more factors. Some of the most commonly cited factors include:

- 1) Stereotypes and perceptions of people in the industry being 'geeky' [19],
- 2) A preponderance of male-oriented computer games (Hartmann & Klimmt, 2006),
- 3) A lack of female role models [20],
- 4) A lack early access to computers [21],
- 5) Academic exposure - limited computer coursework in high school [22],
- 6) Social encouragement - family and school influences (Croasdell, McLeod, & Simkin, 2011),
- 7) Career perceptions that computer work is tedious and socially isolated [23].

2.1 Stereotypes about Those in the Industry

Negative stereotypes sometimes referred to as the 'nerd factor', are often cited as one of the key reasons why women choose not to pursue technical careers [24]. The way particular groups are represented in the media and popular culture (e.g., television, film, blogs, newspapers, etc.) has a strong influence on how others think about those individuals and their relationship to them. For many years, popular culture portrayed computer professionals as almost exclusively male, unfashionable, socially awkward, overly intellectual, introverted, and poor communicators [25]. These characteristics contrast sharply with traditionally feminine values and are considered unappealing [26].

2.2 Male-Focused Computer Games

Computer games will generate an estimated \$159 billion in revenue in 2020 [27]. It has been a critical sector in the industry since Atari released the first commercially successful video game Pong in 1972. Throughout the history of the personal computer, most games have been overtly developed for and marketed to males. This trend continues with only 5% of contemporary computer games, having a female protagonist [28]. Prior to the Internet's public availability, computer games were the most popular application on personal computers for young people. Some have postulated that by making the computer inherently more appealing

to boys in the past, the gaming industry contributed to the gender gap that we see today [29]

2.3 Lack of Female Role Models

The decline of women in computing occupations has led to fewer female role models for girls considering the field. Researchers have suggested that this lack of visibility and external influencers contributes to the gender gap in tech occupations [30]. The lack of women in the profession also corresponds with a low percentage of female college faculty in the computing fields [31].

2.4 Lack of Early Computer Access

Differences in ownership, access to, and use of computers at early ages (i.e., pre-high school) have been associated with differences between males and females in their attitudes towards computer technology (Main & Schimpf, 2017). Statistics published by the Women into Science and Engineering campaign (WISE) showed that in 1984 only 5% of adult women and 19% of girls were using a computer at home. In contrast, 25% of adult males and 51% of boys were using computers [32]. These early disparities are thought to contribute to the differences between male and female participation in computing.

2.5 Limited Early Coursework in Computing

Studies have shown that women tend to be further along in their academic studies than their male counterparts when exposed to their first computer course [33]. In particular, female students are less likely to have taken computer courses in high school [34]. This lack of early exposure to computer technology, particularly during formative years, is thought to contribute to the lack of computing participation as an academic major and career later in life.

2.6 Career Perceptions That Computing is Boring

Google [23] released a study examining the determinants of choosing or rejecting computer science as a career. In addition to social encouragement, role models, and academic exposure, the study found that the second most crucial factor for a young woman choosing or rejecting a computing career is their perception of the field and associated occupations. Females

who were not familiar with computer science tend to view it as tedious and laborious (Kadilevich, 2000). Such perceptions often lead otherwise well-qualified individuals towards other career paths [35].

Although the prior research examines different aspects of the problem, most of these studies focus on a single cause for the decline (e.g., computer games are male-centric). The associated prescription typically calls for some change in what is seen as the cause (software companies should develop more female-friendly computer games). Despite these findings, the trend continues, and none of the prescriptions have either been effectively implemented or shifted the outcome [9].

3. METHODOLOGY

This project is part of a more extensive longitudinal study conducted between 2003-2020. The larger study seeks to understand better the complex system of motivations that many students consider when choosing an academic major. Further, the more extensive research also seeks to understand better the key reasons why students reject specific majors (information technology/computer science in particular), even when the data suggest that the choice should otherwise be appealing.

The survey instrument was derived from prior work reported in the literature [11,26,36]. Often, such surveys are given to students who have already selected a particular major. Such convenience sampling can lead to distorted results. For this study, the questionnaire was administered to 943 participants between 2003 and 2020. Respondents were drawn from diverse educational backgrounds. This study includes students from various academic programs, declared and undeclared majors, and different school years (freshmen – senior). 91.1% of the participants were traditional college-age students (18-24 years old). 54.5% of the respondents were male; 45.5% were female.

The survey explores issues identified in prior research, perceptions about the computer field, motivations for major selection in college, reasons why technology majors are or are not chosen and descriptive information about each respondent. The surveys were administered anonymously, the study's objectives were presented, and participation was voluntary. Student assistants coded the responses to

provide a degree of isolation from the investigators.

4. RESULTS AND DISCUSSION

The objective of this investigation is to determine if there have been shifts over the past two decades in terms of women and their perceptions of and relationship to technology, academic majors, and computing career opportunities. Responses were broken out by gender and compared to each other. More recent data was also compared to the preliminary results from 2010 [37]. The results for the influencing factors are presented below.

4.1 Stereotypes about Those in the Industry

Data collected as part of this study suggests that the issues related to stereotypes are less of a problem than they may have been in the past. Although stereotypes still exist, their negative impact appears to be less impactful. Of particular interest were the differences between male and female respondents. Findings indicate that female respondents disagree more strongly than their male colleagues regarding some key stereotypes (see Fig. 2). Over 60% of females disagreed with the notions that computer majors are 'nerds' and that as a group, they tend to be less social than students in other fields. This

change in perception may be due to the rise of the computer industry, the public awareness of many "nerdy" professionals accumulating large fortunes, and the widespread ownership and use of computers, smartphones, and related technology [38].

Although the majority of female participants hold a less negative view of people in the computing field, approximately 80% still assume that computer majors will work as programmers after graduation, that successful computer majors have significant technology backgrounds and training, and that most computer majors are devoted computer hobbyists in their personal lives.

4.2 Male-Focused Computer Games

Although games have long been targeted at male consumers, a growing number of females now identify themselves as either casual or serious gamers. The data collected in this study is consistent with broader research that suggests women may be overtaking men in certain aspects of gaming. In 2015, a study released by Pew Research showed that 37% of males and 42% of females owned a video-game console [39]. With the rise of the Internet and growth in other software types, games are no longer the dominant application for personal computers and appear to be a less significant influencer [40].

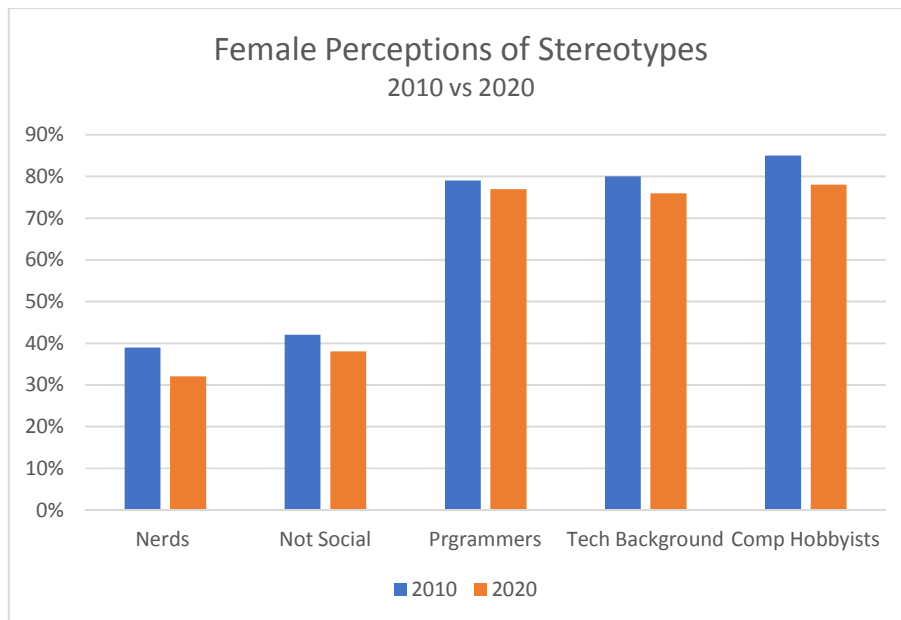


Fig. 2. Female perception of I.T. stereotypes

4.3 Lack of Female Role Models

The lack of women choosing to study computing and work in the technology industry over the past several decades has resulted in fewer female role models who can serve as a positive influence for younger girls. This study confirms that this continues to be a problem, with most female respondents indicating that the lack of female visibility in technology had a negative effect on their perception of the field. Although not explicitly captured in the survey, subsequent debriefing indicates that the perceived lack of females in advanced computer courses in college creates somewhat of a vicious circle that discourages otherwise interested women from taking the classes.

4.4 Lack of Early Computer Access

Past disparities in early access to computers and related technology are no longer an issue in 2020. Both female and male respondents reported equal access to technology growing up at home, with approximately 75% having a household computer available to them when growing up (see Fig. 3). This result is consistent with U.S. Census data that estimates that 77% of U.S. households own a desktop or laptop computer [41].

4.5 Limited Early Coursework in Computing

The longitudinal data collected in this study shows a dramatic shift in terms of early computer coursework. Before 2010, most respondents indicated that their high schools either didn't offer computer classes or that such courses were electives (not required). In 2010, males were twice as likely as females to take an optional

computer class. By 2020, most of those surveyed indicated that computer classes were almost universally available at their high schools and that most required at least one course be taken (see Fig. 4).

It should be noted that the majority of respondents in this study grew up in a state that includes demonstrating technical competency as a requirement for high school graduation. A growing number of states have similar requirements and the availability of computer courses in K-12 is expected to further reduce the imbalance [42].

4.6 Career Perceptions That Computing is Boring

The perception that computing is an inherently dull subject and that work in the computing field is also dull and socially isolated is an opinion held by male and female respondents. Between 2010 and 2020, the data indicates less of a difference observed between the sexes, but the perception still widely exists (see Fig. 5).

The data seems to suggest that much of this may be grounded in how respondents view computer programming. The majority of both female and male respondents indicated that they did not enjoy computer programming and viewed required courses in programming as a negative factor in their major-selection decision. In particular, female students expressed a strong aversion to programming early in their major program of study. During follow-up debriefings with the respondents, we asked them to identify better alternatives. Courses such as web design, social implications of technology, and data analytics were suggested as more attractive starting points for a computing curriculum.

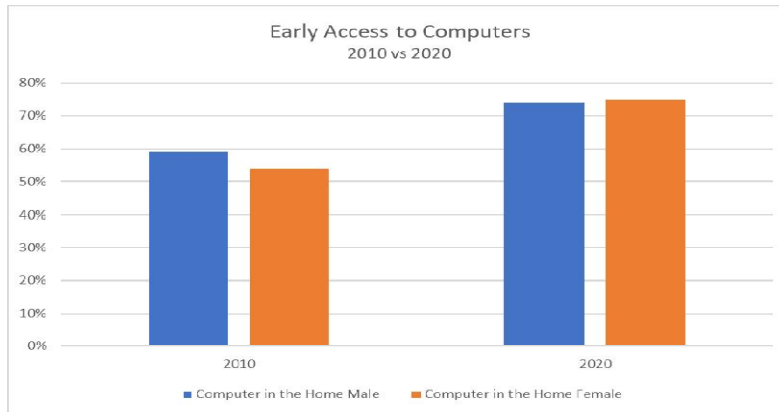


Fig. 3. Early access to computers

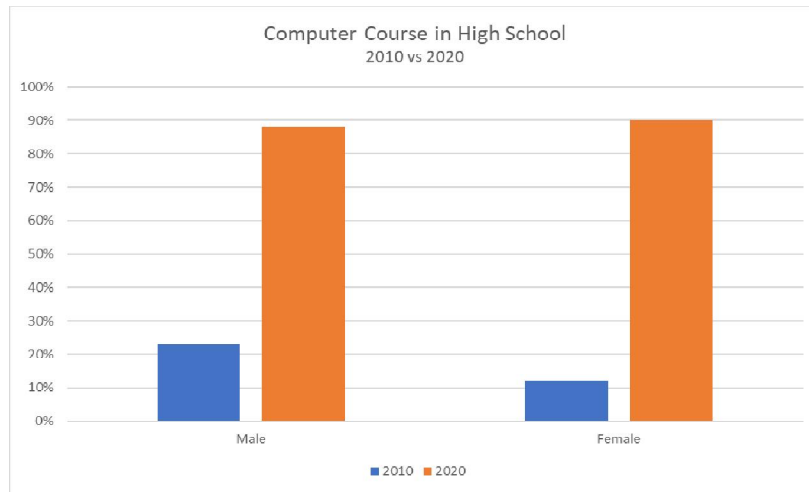


Fig. 4. Computer course taken in high school

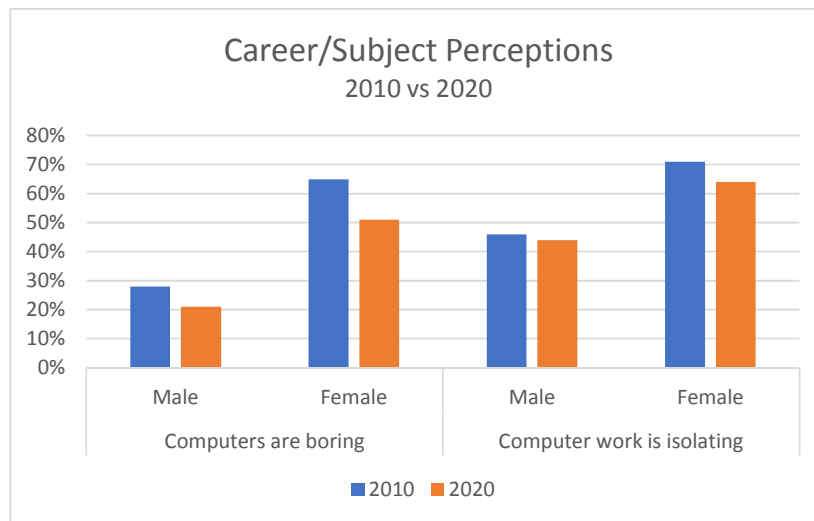


Fig. 5. Career Perceptions between 2010 and 2020

5. CONCLUSION

As the technology sector continues to flourish and grow, the need for skilled computer professionals will likely continue to be strong. The decline in female participation in this area is a cause for significant concern. It is not the goal of this study to offer up another alternative explanation for the phenomenon, but rather to re-examine past research and the applicability of prior findings to contemporary Gen-Z students.

The data suggests that some of the earlier obstacles to computer interest are no longer as impactful as they may have been in the past. Negative stereotypes about people who

study computers and work in the field still exist, but the perceptions are evolving with greater acceptance of so-called 'nerd' characteristics. Many computer games are still developed for the male market, but women are increasingly identifying themselves as gamers. The disparity that once existed for early access to computers and computer classes is no longer an issue, and males and females both report equal ownership of personal technology such as cell phones and laptops.

Some obstacles that have been reported in the literature are still problematic. For example, the overall lack of women who study and work in computing creates a lack of female role

models. This fact is a vicious-circle problem that will require significant intervention to remedy. A growing number of technology companies are starting to address this proactively and it's hoped that in time, this situation can improve.

Such efforts, however, are likely to be hampered by the ongoing perception that computing, computer programming, and working in technical occupations are inherently dull, isolating, and unappealing. We found the debriefing feedback that suggested that other aspects of the computing field are attractive to women to be encouraging. Although software and web development continue to be the largest segment of the tech industry, the computing field is large and evolving. As such, there are growing opportunities in other areas of the industry that may be more broadly appealing.

Although there are still serious obstacles to women considering studying and pursuing careers in the computing fields, this study suggests that some of the traditional barriers may no longer be as significant as they once were. Academic institutions seeking to increase the number of female students in their technology programs are encouraged to conduct similar surveys to better understand major and career selection determinants for their populations. These will likely vary from country to country and between regions of the same country. As such, these findings cannot be broadly generalized to the overall population. Additional research in this area is needed to better understand today's Gen-Z students' shifting demographics, perceptions, and motivations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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