Women's Participation in Engineering between 2011 - 2019

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ABSTRACT

Despite much effort by engineering education scholarships to make engineering more inclusive, women are still underrepresented in engineering. Women earn less than 30% of the bachelor's degrees in engineering. However, when we examine the intersectionality between gender and race/ethnicity, the lack of representation in certain groups of women tells us that some women are more underrepresented than others. There is no question barriers within and outside educational forums still prevent women, and in particular women of color, from entering the world of engineering. The barriers include poor advising, lack of mathematics preparation, poor pedagogy, a difficult curriculum, lack of preparation, an unwelcoming culture for women and minorities, and lack of mentorship. The more systemic barriers include the history of exclusion of women from engineering until the 1970s, and past and present systemic racism in United States education which has influenced the experiences of women across different racial and ethnic groups in engineering.

Women earn less than 30% of the bachelor's degrees in engineering. From 2011 to 2019, the percentage of women who earned a bachelor's degree increased by 6% from 20.4% in 2011. Therefore, in 2019, women represented 50.8% of the U.S. population, but only 26.4% of the engineering bachelor's degree holders. Moreover, not all ethnic and racial groups of women experienced an increase in degree attainment. Within this period, American Indian or Alaska Natives have experienced a slight decrease, while Asians, African Americans, Hispanics, and White women have experienced increases in varying degrees. White women have experienced the most gains in bachelor's degrees, but all categories of women, except for Asian, represented a lower percentage of engineering bachelor's degree holders compared to their percentage representation within the U.S. population.

Fortunately, much is known about factors that make women leave engineering. More effort is needed to remove these know barriers to make engineering more inclusive and to allow more women to successfully complete their engineering bachelor's degrees.

INTRODUCTION

The diversity problem in engineering is simply considered a matter of fact. In other words, no one disagrees that engineering has a diversity problem. When it comes to women's participation in the field, there are several reasons for this specific lack of diversity. Some are comprehensively captured in the history of women being barred from and kept away from engineering studies up until the 1970s (Bix, 2013). Reforms have focused on policies protecting women from overt exclusionary practices.

There are many other reasons for the lack of women's representation in engineering. A seminal study by Seymour and Hewitt (1997) shed light on why the few women who have a high demonstrated ability when entering science, mathematics, and engineering (SME) disciplines, lose confidence after their entry into these fields, becoming more vulnerable to switching out than their male majority peers. Today, a plethora of scholarships exist identifying various reasons, needed changes, and interventions to reduce the inequity in engineering education and remediate the overt and covert discriminatory practices making engineering exclusively male.

What are some of the things that we know?

A study by Tyson et al. (2010) identified poor advising, mathematics preparation, and fitting in as reasons why female and minority students switched or remained in engineering. Poor advising was one area switchers from engineering had in common. These students were not given enough information to help them know what to expect in an engineering program. Therefore, they found their interest did not fit with the engineering curriculum and switched, despite the promise of the field's financial rewards. In addition, switchers were not prepared by school counselors regarding the mathematical skills required in engineering. Even those who were well prepared in mathematics and sciences switched because of difficulty adjusting to their transition from high school to college. Lastly, fitting in with those who persisted was also a factor for those who switched. These students had difficulty connecting

with those who persisted, as they were seen to be of a certain "geek or nerd culture within engineering" (Tyson et al., 2010, p. 73).

Other studies focus on pedagogy, curriculum difficulty, lack of preparation, and lack of belonging as factors that influence students' decision to transfer out of engineering. For example, most engineering professors still use lectures and only use interactive strategies occasionally as an alternative to lectures (Heppner et al., 2010). So, students are essentially passive, disengaged recipients of knowledge in engineering classrooms. In addition, students who reported their high school preparation for engineering was inadequate also reported higher levels of difficulty in engineering curriculum (Marra et al., 2012). Moreover, students' confidence in completing their engineering degree decreased as their perception of belonging decreased (Marra et al., 2012). Gender and racial minorities, such as African Americans or women who were also racial or ethnic minorities felt further isolated. This had an impact on their perception of belonging (Tyson et al., 2010). According to Mills et al. (2013), since female students are a minority in engineering classrooms, their marginalization may be normalized, so some female students feel uncomfortable and excluded, resulting in their withdrawal or lack of success in their studies.

Students' prior experiences have an impact on their perceptions of learning engineering. Generally, it is assumed all students have the same level of technical capital upon entering engineering. Noravian (2014) defined technical capital as experience with tinkering, manipulating tools, doing hands-on work, and knowing the process of solving problems requiring technical solutions. Since students' perception of what they learn and making sense of what they learn is linked to their prior knowledge of how things work (Macaulay & Ardley, 1998), then students who may not have had the opportunity to develop technical capital before entering engineering school may be less likely to make sense of their experiences as meaningful or useful. Many female students are less likely to have been given the opportunity to develop their technical capital before entering engineering school. Without supporting their development in this area, they may be more likely to exit engineering.

The way in which engineering culture is defined and seen may be another factor that influences how women experience engineering school. Godfrey and Parker (2010) define culture in engineering education as having the following dimensions: (A) an engineering way of thinking, which means "unique ways of knowing or thinking relevant to

engineering, sometimes in relation to other academic disciplines;" (B) an engineering ways of doing, which means "shared beliefs and assumptions around how teaching and learning" in engineering is done; (C) being an engineer, which that there are "attributes and qualities in being an engineer;" (D) acceptance of difference, which identified differences between the cultural norms around teaching and learning of older faculty versus younger faculty, faculty from different disciplinary backgrounds, representation of different racial and gender groups among faculty and students, and the relationships between these groups; (E) relationships, which are assumptions around the "right way for people to relate to one another;" and (F) relationship to the environment, which was described as "the school of engineering's shared assumptions and beliefs around its relationship with the rest of the university and the engineering profession." Since Forde et al. (2010) defined culture as what women and minority students think and do, it can be ascertained that some women identify as engineers, while some don't, within all the various dimensions mentioned by Godfrey and Parker (2010). In other words, what women think and what they do may or may not fit in with the various dimensions of culture in engineering education. Those who do not fit in are likely to exit.

Forde et al. (2010) tell us that students' perceptions on how they are valued by faculty and being mentored by them has an impact on their experiences in engineering. Students reported that faculty placed higher value on research than teaching, and they found faculty unhelpful during office hours. In addition, undergraduate students felt graduate students were given higher priority because of their interest in research. Lack of mentorship was also problematic, particularly for women who would benefit most from mentoring. Therefore, institutional support which they define as "support through student organizations, department staff, flexible course scheduling, and provision of social activities" (Forde et al., 2010, p. 143) was seen as lacking for women and minority students. This led students to feel they were not given the information about programs intended to support students, and faculty's communications and behaviors led them to feel they were not valued. These perceptions and experiences are likely to drive women out of engineering.

Students' gender, racial and ethnic identities impact how well students perceive their fit. Wao and Lee (2010) tell us that gender and racial differences in fit have an impact on the higher levels of trepidation female and underrepresented students felt about fitting in academically and socially. For example, when students didn't see those who looked

like them, they didn't feel there were others who were like them or thought like them. This gave them a sense of not fitting in.

Mental health and stereotype threat also have consequences on women, underrepresented populations, and first-generation students' sense of belonging and their retention in engineering programs. Jensen et al. (2021) found that levels of stress, anxiety, and depression are high for engineering students. But the level of stress and anxiety are significantly higher for female students. They also found that women and students who are underrepresented are more susceptible to stereotype threat than those who are the dominant group in engineering. In addition, students who were first-generation undergraduate students experienced higher levels of depression and stress compared to their peers.

The transition from a 2-year to a 4-year institution is an additional challenge faced by women, students of color, and low-income students. A community college is the first step in post-secondary education for many students in the United States. Of the 4.9 million students enrolled in 2-year public institutions, 66% were enrolled part-time, 59% were women, 30% were first generation to attend college, 16% were single parents, 56% received some kind of financial aid, 46% were racial/ethnic minorities, and their average age was 27 (AACC, 2023). Moreover, community college students are likely to be academically underprepared (Bailey & Morest, 2006). Thus, nationally women, students of color, and low-income students are more likely to attend community college than a 4-year college. More importantly, 49.2% of bachelor's degree recipients start their educational journey in a community college (Glynn, 2019; Shapiro et al., 2015). But community college students who successfully transfer to 4-year institutions experience more challenges than their peers who started at a 4-year institution (Handel & Williams, 2012). Whaler and Miller (2010) and Zhang (2022) focus on the 2-to-4-year institutional transfer experiences of students in science, technology, engineering, and math (STEM). They found the more male-centered engineering programs provided a chilly climate for females and underrepresented students, making them feel excluded from engineering programs, which made it more challenging for them to adjust to engineering programs. However, this challenge was further compounded by the transition from a 2- to 4-year college where they also faced much larger class sizes, less faculty availability and poor support, lack of social networks and study groups, and financial constraints outside of school.

Lastly, women represent a rich diversity of racial and ethnic groups. It is known that underrepresentation of racial and ethnic minorities in education is due to past and present systemic racism in U.S. education (Feagin & Barnett, 2004; Slaton, 2010). Therefore, the experiences of women vary across different racial and ethnic groups.

Knowing what we know, how have things changed in the past decade?

From 2011 - 2019, the percentage of women in the U.S. has consistently been 50.8% (USA Facts: Population, 2023). Because the Coronavirus disease (COVID-19) pandemic had a significant impact on health and education in 2020, it has been left out of this review. Prior to COVID-19, this period is considered a "decade of disruption" (Palandrani, 2020) technologically that has influenced all aspects of our lives, including communication, socialization, medicine, transportation, and space travel, to name a few. Interestingly, the author's personal observations from attending American Society for Engineering Education conferences and consuming the literature on engineering education, have been that many engineering education scholars who author articles and attend educational conferences are women. This makes at least engineering education look much more inclusive than perhaps other engineering conferences. So, knowing what we know about engineering education prior and during the last decade, have things changed in engineering to make it more inclusive of women, particularly women from different racial and ethnic backgrounds? Has the demand and growth in technology driven an increase in the number of women engineers?

To answer these questions, one needs to examine whether there has been a change in women's representation in engineering from 2011 - 2019. Entry into the field of engineering requires at least a bachelor's degree. Therefore, the number of bachelor's degrees is a measure for the extent to which any demographic is represented in engineering. Associate degree recipients are a measure of future participation in engineering. National Science Foundation data for associate and bachelor's degrees from 2011 - 2019 (National Center for Education Statistics, 2023) is used to explore the extent to which women have (in the case of bachelor's degrees) or potentially could complete (in the case of associates degrees) the educational attainment to enter the field of engineering. Table 1 shows the percentage of engineering associate and bachelor's degrees earned by all women who are either U.S. citizens or permanent residents in 2011 - 2019. It shows the percentage of women

who earned a bachelor's degree increased by 6%, up from 20.4% in 2011. Therefore, in 2019, women represented 50.8% of the U.S. population, but only 26.4% (or a little over a quarter) of the engineering bachelor's degree recipients that year. This period also saw an increase of 3.1% in the number of women who earned an associate degree in engineering from 17.1% to 20.2%.

Table 1. Percentage of Engineering Degrees Earned by Women from 2011-2019.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Associate degrees	17.1%	15.8%	16.6%	15.9%	16.4%	17.5%	19.1%	20.4%	20.2%
Bachelor's degrees	20.4%	21.0%	21.2%	21.9%	22.5%	23.6%	24.6%	25.5%	26.4%

When data for different ethnic and racial groups of women are examined, not all groups experienced an increase in bachelor's degree attainment. Table 2 shows the percentage of bachelor's degrees earned by women from different racial and ethnic groups from 2011 - 2019 (National Center for Education Statistics, 2023). American Indian or Alaska Natives have experienced a decrease from 0.12% in 2011 to 0.08% in 2019. Asians have increased from 2.97% to 3.88%, a change of <1%. African Americans have experienced a change from 0.05% to 0.10%, which is an increase of 0.05%. Hispanics have experienced an increase of 1.24% from 2.11% in 2011 and White women have experienced an increase of 3.15% from 12.59% in 2011. Native Hawaiian or Other Pacific Islanders bachelor's degree attainment has fluctuated between 0.03% to 0.05% during this period. So, the most gains in bachelor's degrees have been by White women.

Table 2. Percentage of Engineering Degrees Earned by Women from Different Racial/Ethnic Groups from 2011-2019.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
American Indian or Alaska Native	0.12%	0.10%	0.11%	0.11%	0.09%	0.07%	0.06%	0.09%	0.08%
Asian	2.97%	2.99%	3.06%	3.05%	3.13%	3.39%	3.59%	3.81%	3.88%

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	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
African American	0.05%	0.05%	0.04%	0.05%	0.04%	0.07%	0.05%	0.08%	0.10%
Native Hawaiian or Other Pacific Islander	0.04%	0.05%	0.05%	0.05%	0.04%	0.04%	0.04%	0.03%	0.04%
Hispanic	2.11%	2.31%	2.36%	2.52%	2.71%	2.87%	3.07%	3.25%	3.35%
White	12.59%	13.04%	13.09%	13.57%	13.77%	14.31%	14.81%	15.22%	15.74%

The year 2019 is used to compare the overall representation of women from different racial and ethnic groups in the U.S. population with the percentage of women who earned bachelor's degrees in engineering. Table 3 shows that all categories of women, except for Asian, represented a lower percentage of engineering bachelor's degree holders compared to their percentage representation within the U.S. population. For instance, Asian women represented 2.9% of the U.S. population, but attained 3.88% of the bachelor's degrees in engineering. White women represented 30.5%, but only 15.74% of engineering bachelor's degree holders. They were followed next by Hispanic women who represented 9.4%, but only 3.35% of the bachelor's degree holders, and Native Hawaiian or Other Pacific Islander women who represented 0.1%, but only 0.04% of bachelor's degree holders. Finally, African American women represented 6.4% of the population, but only 0.1% of bachelor's degree holders.

Table 3. Percentage of Women in the U.S. and Women Who Earned Engineering Bachelor's Degrees in 2019.		
	Women in the U.S. population	**Women who earned engineering bachelor's degrees**
All women	50.8%	26.4%
American Indian or Alaska Native	0.4%	0.08%
Asian	2.9%	3.88%

Table 3. Percentage of Women in the U.S. and Women Who Earned Engineering Bachelor's Degrees in 2019.		
	Women in the U.S. population	**Women who earned engineering bachelor's degrees**
African American	6.4%	0.10%
Native Hawaiian or Other Pacific Islander	0.1%	0.04%
Hispanic	9.4%	3.35%
White	30.5%	15.74%

What does this mean?

As mentioned previously, a minimum requirement for individuals entering engineering is a bachelor's degree. During 2011 - 2019 women were 50.8% of the total U.S. population, and their engineering bachelor's degree attainment increased by 6% to 26.4% by 2019. This indicates women remain largely underrepresented in the engineering workforce. In addition, specific racial and ethnic groups of women are more underrepresented than others. However, the number of women who have received an associate degree has increased slightly. This could mean these individuals will earn a bachelor's degree if they are able to successfully transfer and complete an engineering degree.

Often discussions of the importance of women in engineering are put in terms of economic growth for the country or higher standard of living made possible by high paying engineering jobs. However, the participation of women in engineering is important beyond just economics. Engineers contribute to solutions for various problems that plague humanity. If women are underrepresented so significantly in engineering, their voices would not be heard when it comes to the identification, selection, and development of solutions to problems that are important for at least 50% of the world's population. This problem is even worse for ethnic and racial groups that are more underrepresented in engineering. For example, Mary Anderson developed the idea of windscreen wipers in 1905, a concept that wasn't initially accepted by many in the automotive industry. It was after her patent expired that the wiper became adopted by the industry (Shepherd, 2023). Moreover, women who have contributed to engineering are rarely, if at all, acknowledged. The list of such women from the past include a famous

actress, Hedy Lamarr (1914 - 2000), who held several patents related to wireless communications and without whom we may not have Wi-Fi today (Shepherd, 2023).

Optimistically, if the incremental change of 6% we have seen in 2011 - 2019 continues every decade, then perhaps it is possible the number of women who obtain a bachelor's degree in engineering could reach 50% by the 2050s. The question is whether the world can wait that long given the state of the planet and society. Also, if this is an optimistic projection, one has to ask what the more realistic scenario would be. There has never been any evidence that women's cognitive skills, their intellectual interests, their ability to excel in math and science, their aspirations, or anything else needed to become engineers are lacking. There is no question that barriers within and outside of educational forums still prevent women, and in particular women of color, from entering the world of engineering.

It is difficult to look at this data and imagine, despite all the knowledge of what makes women leave engineering, much more effort is needed in engineering education to make engineering more inclusive. Despite 2011 - 2019 being considered a decade of technological disruption, little has changed for women in engineering degree attainment. Unfortunately, it is still true that plus ça change, plus c'est la même chose (the more things change, the more they stay the same; Rosser, 2012).

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