PANEL: After #MeToo: What's next for Women in the Engineering Workplace?

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Abstract

This paper (and corresponding panel session at ASEE 2019) seeks to provide researchers who have an interest or potential interest in studying women engineers in the workplace (academic, corporate, government, nonprofit) with tools to support that research. The #MeToo movement has raised awareness regarding sexual harassment, abuse, and assault in the workplace to historical highs. Concurrently, the movement has stimulated a greater interest in understanding forces in the workplace which hinder or promote the advancement of women. Insight into the types of experiences that women have in corporate, academic, nonprofit, and government workplaces, as well as how these experiences have and will be shaping career and life choices is critical to expanding understanding. Our hope is that such renewed interest and expanding insight will lead to useful revelations regarding how, where, and when women experience hostile, unwelcoming, or otherwise difficult working conditions that ultimately lead them away from engineering, into other roles whether they remain in the workforce or exit it altogether.

Engineering, with its historically stubborn gender gap, is of particular interest to researchers as the cultures, habits, and behavioral patterns that underlie many engineering work environments may limit how the participation of women at all levels can be broadened and improved. This paper provides a brief historical overview of women in the workplace, a more focused summary of studies of women in the engineering workplace, and a brief overview of the research tools, both quantitative and qualitative, that are suited to this area of research.

Introduction

Tarana Burke, a black civil rights activist from New York, originally coined the phrase Me Too in 2006 in order to raise awareness regarding sexual assault and abuse among women of color and to promote empowerment among women who had been abused. On October 15, 2017, the term went viral on twitter as #MeToo when actress Alyssa Milano encouraged those who had been sexually harassed or assaulted to use the hashtag to draw attention to these issues. The current movement was stimulated by sexual assault allegations against the film producer Harvey Weinstein earlier in 2017. Since 2017, the number of allegations for sexually based misbehavior and criminal acts against women has skyrocketed, as women have come forward from many walks of life to speak of their experiences [1].

The #MeToo movement has also stimulated renewed concerns about a lack of diversity in certain industries, including high technology and engineering, as well as a more critical eye toward gender-based differences in pay, status, promotion, and other imbalances in American society and in many other countries around the world. Not unexpectedly, the movement has led to backlash, as some accusations inevitably have been inadequately fact-checked, exaggerated, or misunderstood. As both men and women seek to adjust to the post #MeToo workplace, men have often withdrawn in confusion as to what remains appropriate and what might be construed as inappropriate behavior in the workplace. Many avoid conversations on the topic for fear of negative consequences. Yet, silence and withdrawal are the enemies of productive forward-looking change in workplace norms and behavior as a result of and response to #MeToo [1].

Regrettably, science and engineering fields lead the way in relative silence. While in many fields and industries, those who sexually harass have lost their jobs, in the sciences and engineering, they are often still working as if nothing has happened. Women working in the sciences or engineering who are victims of sexual misconduct are rarely aware of a means to report or formally respond to harassment. Even fewer report such abuses, yet most suffer significant career consequences from such experiences [1]. Worse, in the larger picture, sexual harassment and misconduct are only one of many barriers that women face in the sciences and engineering [2].

Yet, while women make up only 14.5% of the engineering workforce [3], [4] they are a significant human resource for filling shortages in the engineering workforce because they represent approximately 19.8% of all bachelor's degrees and 24.2% of all master's degrees in engineering [4]. Despite extensive efforts to reach gender parity in engineering [5], engineering remains stubbornly resistant to providing a compelling and welcoming environment for women while other fields like biology and math have advanced to much greater gender balance at 60% and 42% women respectively [6].

Women bring diversity of thought into engineering that reduces "...opportunity cost - a cost in products not built, in designs not considered, in constraints not understood, in processes not invented" [7]. Thus, understanding the challenges that women face in the engineering workforce, including but not limited to sexual harassment, is critical to bringing the benefits of this diversity of thought into engineering and reducing the large numbers of women engineers who begin a career in engineering and later decide to leave [8]. The peer reviewed literature provides insight into which women are leaving engineering and why, but gaps remain in workplace studies to provide a sufficiently comprehensive understanding of what’s going on so that major steps forward are possible.

Women in the Workplace

Pre-Twentieth Century: The assumption that women have not contributed to institutional work settings or the incomes of their families prior to the twentieth century is false. Previous research has established that prior to the Industrial Revolution during the nineteenth century, European and American women contributed to a civilian labor force alongside their male counterparts. For example, under feudal serf economies in Europe (e.g. circa 1750), most serf-level labor consisted of farm work. While labor was divided on a gender basis on the farms, all members of the household contributed to the field and husbandry efforts. In urban settings, men and women were equally likely to work as servants or even within early manufacturing jobs, such as workhouses, workshops, or artisan occupations [9]. According to historian Alice Kessler-Harris [10], “A preindustrial society assumed that, except among the privileged few, all family members would work as a matter of course,” a norm that seemed to be accepted in Europe and the burgeoning United States until the end of the eighteenth century.

The perception of women's roles in the workplace shifted as the Industrial Revolution gained momentum. During this time, the concept of the "labor force" was institutionalized with the growth of large conglomerates and mass production. According to Padavic and Reskin [9], individuals fell into one of three groups: wage workers, unemployed persons who were actively looking for paid jobs, and the "nonemployed". While "nonemployed" referred to the aristocracy prior to the Industrial Revolution, the aristocratic component was soon eclipsed by a domestic labor force which took primary responsibility for taking care of family members and the many jobs now often termed domestic and "emotional" labor [9], [11]. The institutionalized labor force and the nonemployed (e.g. domestic) labor force quickly split along gender lines [10] as a result of the Industrial Revolution. In 1840, approximately 40 percent of the U.S. labor force consisted of women and children [12], but by 1890, that number had declined to about 17 percent women [13]. This gender split was further reified by the ideology of separate spheres, which called for a separation of family and work, and condemned women for working once they were married [14]. The assumption that "a woman's place is in the home" echoes these ideological assumptions, undergirding the unspoken assumption that if a woman's place was in the home, a man's place was at work [9]. However, early in the twentieth century, these assumptions were challenged as economic calamity and war began to open doors for women in the workforce once again.

Twentieth Century: The twentieth century ushered in increased numbers of women into the labor force, particularly previously unsanctioned married women. However, the positions available to women were highly limited, often perceived as labor akin to the domestic sphere (e.g. housekeeping, laundering, nursing) [15]. During both World War I and World War II, female participation in non-domestic positions grew in order to fill vacancies left by men fighting abroad [9] as well as growth in the factory system. While increased numbers of women worked, the positions they held shifted dramatically after the two world wars. Immediately following the wars, women were laid off from the manufacturing jobs and other jobs requiring more physical labor. In the following years, women took up positions that were more suitable under a separate spheres ideology: clerical, domestic, and service [9], [10]. These shifting roles of women in the workforce did little to shift gender segregation throughout the remainder of the 1940s and the 1950s.

In the 1960s and 1970s, the first of the baby boomers—those children born just after the end of World War II— entered the workforce, coinciding with a number of social shifts. Familial obligations and structural shifts in the American family were reflected in the growing number of women who joined the workforce. Marriage rates among young people declined as people waited longer to marry. Birthrates also declined (in comparison to the boom of the 1950s), household sizes dropped, and divorce rates grew, so that by 1978, women headed over 14 percent of American families. Although occupations continued to remain highly segregated along gender lines, more and more women began to enter the workforce. By 1978, women made up 42% of wage earners, up from 32% in 1950. Among working women, 78 held jobs in sales, service, or factories, while only 22% worked in managerial or professional occupations—and the majority of those were in teaching and nursing [16]. These segregation patterns continued through the 1980s and 1990s even while the overall numbers of women in the workforce increased significantly, peaking at 60.3% of women as wage-earners in 2000 [17].

Today, statistics show that in the United States, following a steady incline from the 1960s onward, women's participation in the civilian labor force peaked in 1999 at approximately 60% and has been in decline since, with a slight incline in the past year (to 57%) [17]. Even though the numbers of women in the labor force have grown, the workforce still remains largely segregated. At some level, men continue to do "men's work" in manufacturing, managerial positions, and professional work, while women did "women's work" in clerical, certain types of retail sales, and service-oriented labor [18], [19].

The assumption that a woman's place is at home (or doing similar tasks) is also reflected in the ongoing concerns that women with domestic responsibilities may be unable to perform their jobs, and are subsequently less profitable as employees—a foundational assumption at the heart of many discriminatory hiring practices [9], [10], [14], [18]. Recent studies support these claims. As of 2000, only 69% of women with one or more children under the age of six worked, compared to 92% of men with young children [20]. Further, only 52% of women worked full-time when raising children under the age of six. In contrast, 90% of men worked full time in these families [20]. The wage gap between men and women in the United States is also significant at approximately twenty percent. Much of this gap is reflected in the difference in wages between men and women with small children. While the wage gap shrinks when controlling for other factors such as higher education status or having older children (school-age), women with children under the age of six receive 18% less in pay than men in the same positions [20]. This wage gap grows substantially for women of color [21].

The separates spheres ideology which in post WWII kept women largely segregated from men in the workforce may contribute to continued occupational segregation [14]. Out of four primary occupational categories identified by Pettit and Hook [20] (professional, managerial, clerical, and production), only clerical workers were majority female in the United States as of 2000. More importantly, these statistics have barely changed since the 1980s, wavering between 55 and 60% rate of women employees. The minority percentages in the other occupational categories have also remained largely the same in the intervening twenty years [20].

A deeper dive into more recent numbers shows that women continue to work along these trends (Figure 1). The Bureau of Labor Statistics [22] reported the following occupational fields consisted of majority women: retail bakeries (61%), personal service providing (54%), retail trade in home furnishings (53.7%), health and personal care (71%), and clothing (73.2%). Women make up 56% of those who work as bank tellers, credit-administrators, lenders, and processing agents, but lag in other areas of the finance sector including commodities brokering and trading (45.4%). Similarly, most clerical positions are also dominated by women, such as collections (69.6%) and public relations (64.3%). Education (62.6%) and other health services (79.9%) also follow this trend [23]. In engineering, women also participate in the workforce at levels that are far below gender parity. Industrial engineering boasts the highest percentage of women at 23%, followed by computer hardware (18.9%), chemical (16.3%), mechanical (10.9%), and electrical (9.4%) [24]. And, despite the fact that mechanical and electrical engineering are among the most popular fields within engineering, these fields graduate the lowest numbers of female students at bachelor's (14.8% and 16%, respectively), master's (14.7% and 23%), and doctoral (16.2% and 19.2%) levels [25].

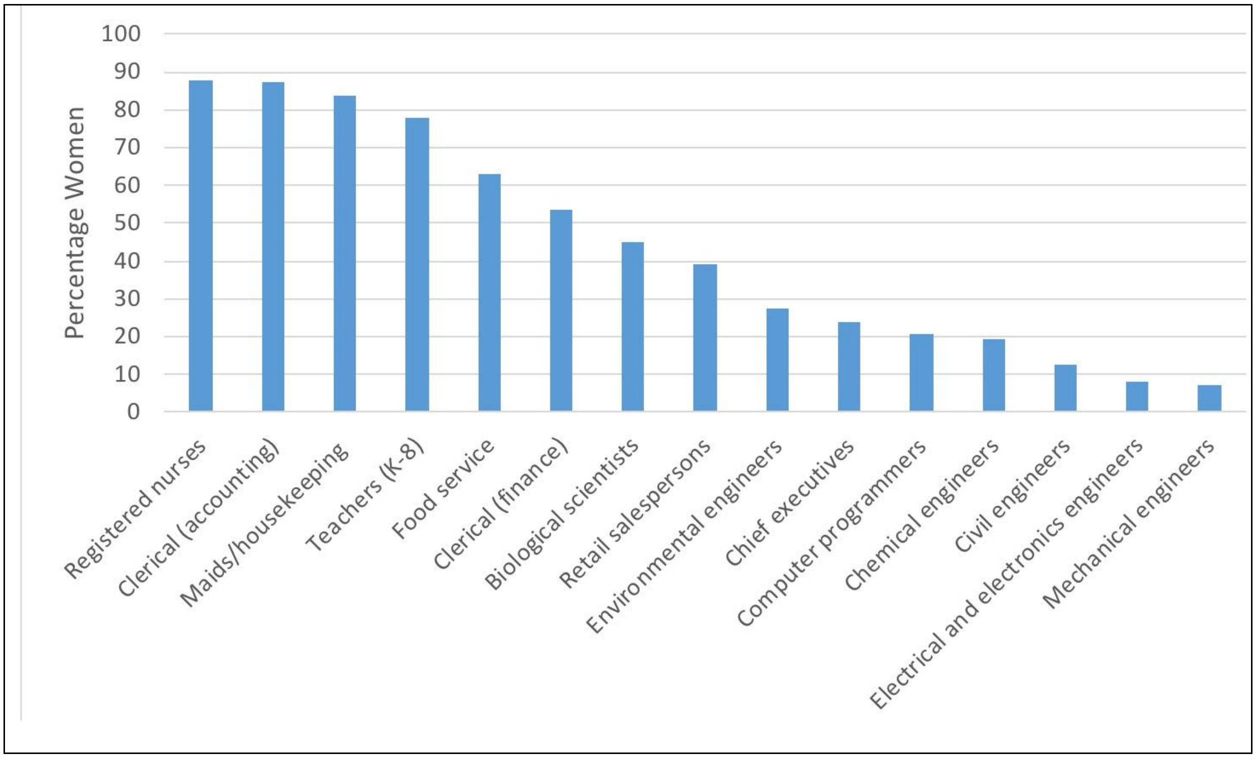
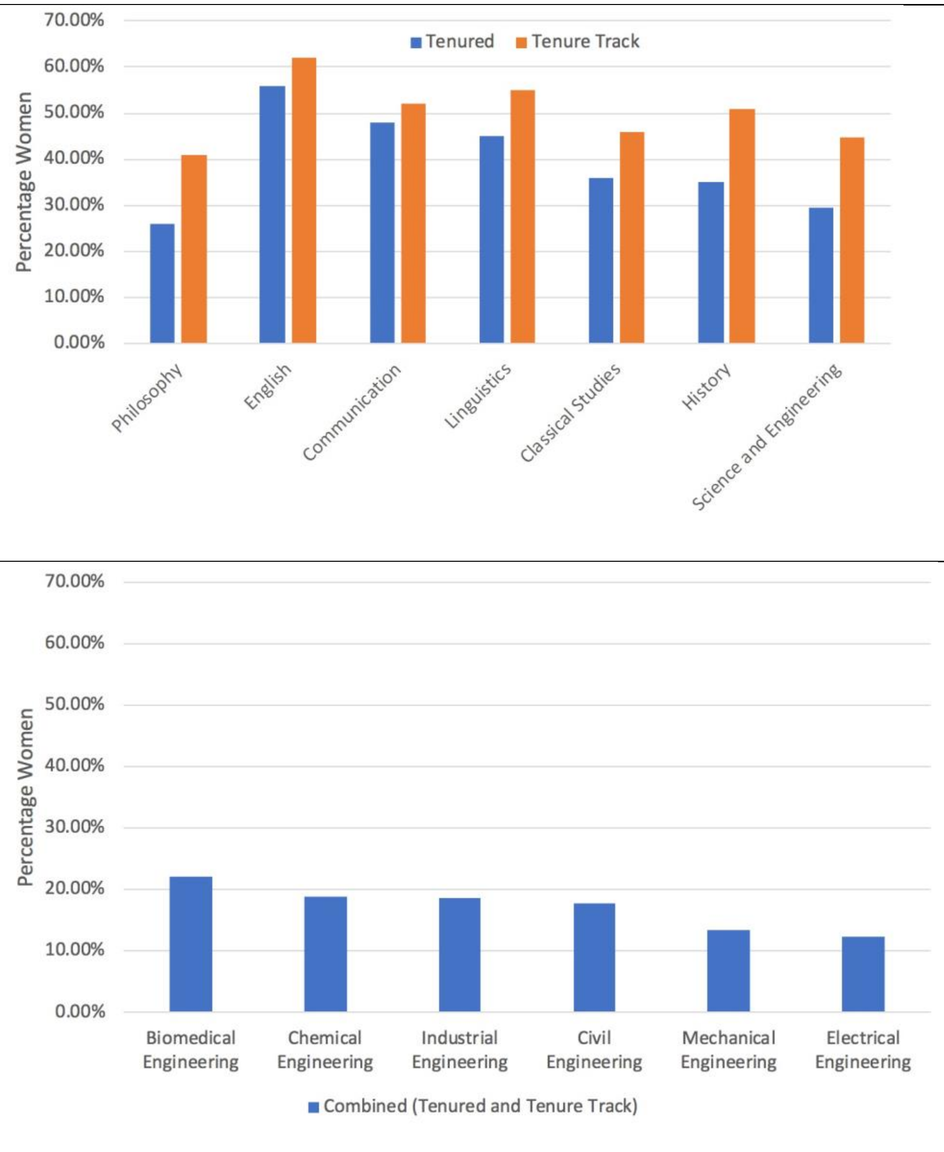


Figure 1: Women in the non-academic workforce in the United States [26]

In the academe (Figure 2), a similar story of occupational segregation and disparity takes place. While Teachers Insurance and Annuity Association of America (TIAA) found in 2013 that women held 49.2% of all faculty positions, they held only 37.6% of tenured positions. Positions are further stratified along disciplinary lines. As of 2013, "women comprised almost two-thirds of the faculty in languages and literatures other than English" and close to half of the faculty positions in the humanities overall [27]. Law schools have also worked toward parity in faculty hiring, where the representation of women faculty has risen to nearly half, up from 22% in 2000 [28]. The percentage of female faculty members at medical schools has also grown by 34% in a similar time period, but the percentage of engineering faculty who are women grew by only 4% [29] to an average representation of 16.9% of tenure track positions in 2017 [25]. Also, women overwhelmingly occupy more adjunct positions than men, a pattern that may again reflect the separate spheres ideological assumption that women need to first and foremost accommodate their families [30].



(a) Science and Engineering vs. Humanities Fields

(b) Within Engineering

Figure 2: Women in tenure track/tenured academic positions in the U.S. [25], [31], [32]

Women in the Engineering Workplace

Historically speaking, women have already made significant progress in the U.S. engineering world. Although the first bachelor's degree was earned by a woman in 1876 [33], many engineering schools refused to enroll women prior to the passage of Title IX in 1972 which required it [34]. It was thus nearly 100 years after the first degree that women first earned more than 1% of all U.S. engineering bachelor's degrees [33]. The percentage of women earning degrees in engineering has increased substantially since 1972 but leveled out at about 20% after 25 years under Title IX [35] (Figure 3), a number still substantially higher than women's engineering workforce participation of 14.5%. Today, women with engineering degrees drop out of the engineering workforce at a much higher rate than men [36], with most leaving in the first 5 years [37] or first 10 years [38] of their career.

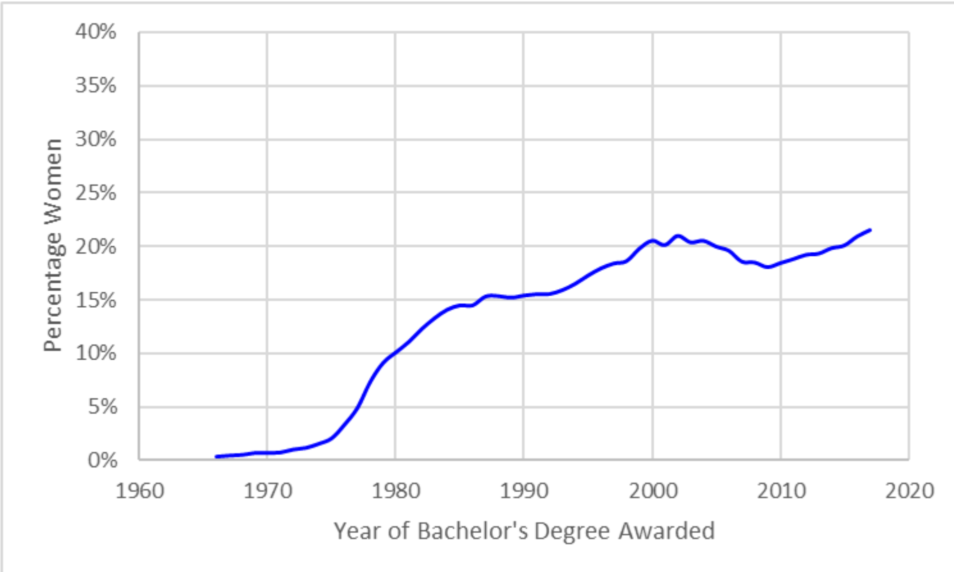


Figure 3: Bachelor's degrees in engineering awarded to women in the U.S. [35]

Issues for Study Design

A complicating factor in studying the engineering workforce is finding a working definition of career persistence. Engineers pursue multiple career paths (engineering manager, project manager, engineering professor, attorney, physician, *etc.*) which may or may not seem like "engineering work" to the individual or to an observer. Thus, a researcher can choose to allow the participant to self-define persistence or can make independent evaluations of participants' current work to evaluate persistence. Quantitative studies may instead rely on databases of employment data; two common sources are the National Science Foundation's Scientists and Engineers Statistical Data System (SESTAT) [39] and the Bureau of Labor and Statistics' Occupational Employment Statistics Survey (OES) [40]. Data from SESTAT and OES tend to be in reasonably close agreement but their different definitions can yield variations. The OES uses *occupations*, defined by the collection of tasks performed and skills required while the SESTAT measures workers who say their jobs require at least a bachelor's degree level of knowledge in science and engineering [41]. As an example of how study design definitions can affect outcomes, a quantitative, longitudinal study found that the percentage of women who were still working full-time 4 to 28 years post-graduation was the same for those whose highest degree was in engineering or in other professional fields [42]. However, a later quantitative, longitudinal study did report women leaving engineering careers more often than other professions [37]. The difference was that the second study tracked not whether the woman was "employed full-time" but if she was employed in an engineering job. Thus, even seemingly simple constructs like "persistence" or "retention" for engineering women requires careful thought match data to intended research questions.

Another troublesome issue of definition is what population of women to study. Some research has been focused exclusively on engineering, but much research is generalized to STEM (science, technology, engineering, and math), or just SET (science, engineering, and technology), S&E (science and engineering), or Tech (technology or high-technology). Some studies define STEM to include all the social sciences and some studies include all technology industry workers, even those without engineering or computer science degrees. Even for research involving only engineering, there is variation in selecting either a single engineering discipline, deliberately sampling a certain distribution, or using whatever disciplines are convenient. While the easy solution has been to treat all studies with a STEM focus as interchangeable, there are multiple ways that population selection could be confounding to drawing conclusions since each of these populations can vary substantially compared to engineering (percentage female, R&D focus, need for PhD, percentage in academia, etc.). For example, a quantitative, longitudinal study of women across many disciplines found that while women did exit STEM at a higher rate than they exited non-STEM careers, the different exit rate overall was due almost completely to only women *engineers* in the STEM population, and in fact the women engineer's higher exit rate was comparable to women's higher exit rates from *all* fields with proportionally more males [43]. Given that gender balance varies so widely across STEM fields, (*e.g.*, in the workforce, psychologists are 76% female, biological scientists are 48% female, and engineers are 14.5% female; within the engineering workforce, industrial engineers are 20% female but electrical and electronics engineers are 9.4% female [44]), this might become an unintentional variable without careful study design.

Women in the Engineering Workplace (Outside of Academia)

From all the statistics, one conclusion is clear: women are substantially under-represented in engineering employment. The "pipeline" model suggests that this problem can be fixed by increasing the input (attracting more girls to study STEM) or by fixing leaks in the pipe (increasing retention). Workforce studies can certainly address the leaks, but potentially can also address the input. It is essential to understand the reasons why women stop working in engineering to be able to improve retention numbers (fix the leaks); it is possible that insights gained will also find ways to make engineering work more attractive to young women (increase input).

Whether qualitative or quantitative, most past engineering workforce research questions center around identifying reasons why women leave or have left engineering after having already earned an engineering degree. Sometimes, workforce studies consider more intermediate steps (before career exit) such as job satisfaction (e.g., [45], organizational commitment (e.g., [46]), career commitment (e.g., [47]) or turnover intention (e.g., [48]); these can each be markers of a woman on the path to leaving or can be a sign of a woman staying but not thriving and not able to perform at her fullest capacity. A few studies have now flipped the questions; these studies instead consider why women have stayed in engineering and asking how (if) they are thriving. (Several websites now index research for women in engineering, including women in the engineering workforce, and are recommended for a more extensive literature review [49], [50].)

Past research has identified reasons for these various outcomes that can be categorized as *structural* (a feature of the environment of engineering educational institutions and workplaces) or *personal* (an aspect of the individual woman or women as a whole). Structural reasons are commonly discussed as *barriers*, and many have been identified. A corporately sponsored multi-national mixed-method study of men and women in SET [38] identified barriers that have been confirmed by other researchers: unclear or stalled career paths, hostile cultures, isolation, diving catch cultures, and extreme work pressures. In the same year, another corporately sponsored quantitative study of men and women working in "high-tech" companies (heavily invested in R&D and making products specific to software development; office machinery and computer manufacturing; electronics; and biotechnology) identified a similar list of barriers: exclusionary culture that did not support women's advancement, inflexible workplaces that were not conducive to work-life effectiveness, isolation, and failure of companies to strategically and objectively identify and develop talent [51]. Personal factors that have been identified include self-efficacy, interest in engineering, intrinsic motivation, and self-identity as an engineer.

Numerical male dominance is defined primarily by the ratio of men to women in an environment while normative male dominance exists when the normative culture is consistent with traditionally masculine traits or characteristics [52]. The two are often interrelated in that numerical male dominance has been shown to be correlated with normative male dominance [53]. Male dominance has been associated with higher levels of sexual harassment and gender harassment (a subset of sexual harassment) but also higher levels of subconscious gender bias which can also have crippling effects on a woman's long-term well-being and career success [54]–[56]. Both numerical and normative male dominance can vary widely between engineering disciplines and engineering workplaces and this should be considered as a part of research design for studying the engineering workforce.

> *"People do not leave companies—rather, they leave supervisors. A direct effect of companies' failure to address the supervisory relationships of technical women will be the loss of highly qualified talent. Likewise, data on the perception of fairness and voice make it amply clear that failure to provide employees with the opportunity to speak up, participate in decision-making processes, and be heard will result in lower employee satisfaction and performance. In an age of increased corporate competition, companies cannot afford these risks."*[51]

Hostile workplace cultures are typically described as "male normative" cultures, where the expectation is that all workers will be male, or at least conform to stereotypical male traits. This can take a variety of forms, including an arrogant, dismissive attitude toward the competence or value of women team members, a macho environment that at best leaves women feeling disregarded and at worst fosters blatant sexual harassment, or unconscious gender bias that penalizes women for displaying "masculine" agentic traits that are required for advancement in the organization or that assumes women will leave when they have children and so takes them less seriously. A large-scale study of SET [38] reported that many women experience hostile cultures. In the high-tech industry, 20% of women felt their career advancement had been stalled due to gender bias [51]. A later quantitative study focused only on engineers reported that 1 in 3 women left engineering altogether because they did not like their workplace climate or boss or culture. Also, 1 in 3 *never* entered engineering work after earning their degree because they expected non-supportive workplace cultures (an indication of opportunities to fix the pipeline input) [57]. A mixed-methods study from Australia determined that women engineers were more dissatisfied with workplace culture and conditions than men; specifically, "36% of women reported that they experienced discrimination while working as engineers, and 27% that they were sexually harassed, compared (respectively) with 8% and 4% of men." One way this discrimination manifested was that 12% of women said they were given less interesting work than their male coworkers, which also led to fewer promotion opportunities [58]. A qualitative study confirmed that women who have left engineering identify the work environment as a factor in that decision [59]. Interviews with younger engineers (from the millennial generation) explored whether there has been generational progress on this issue but unfortunately, a hostile work climate was still the top problem identified by the women millennials. Actually, a hostile work climate was also frequently identified by men millennials, but only for the women was this hostile climate specifically due to gender [60].

It is not just overtly hostile but also "chilly" climates that hurt women in engineering, which often includes women who feel isolated [38]. This has sometimes been identified as women lacking a sense of belonging or relatedness in the workplace [61], a natural result of the rarity of women in the workplace and the tendency for men to formally and informally socialize with each other. In a follow-up to the original Athena Factor study which identified isolation, researchers concluded that it is becoming more common for women in SET to not be "the only one" in their workgroup or location, but they still lack role models and they still feel excluded from the male "buddy system" [62]. Using qualitative methods, Ayre and coworkers focused on Australian women civil engineers who had successfully persisted long-term. Although many of these women had in fact felt marginalized over their careers, these women who successfully persisted had adapted by making career choices that allowed them to create work environments that matched their expectations for supportive, inclusive cultures [63].

Hostile climate and isolation can intersect to leave women without effective mentors or sponsors, which contributes to unclear or stalled career paths. Sometimes these unclear paths are linked to complex corporate structure, with many job levels and classifications. A qualitative study of mid-to-late career Australian women in engineering identified a key reason to leave as difficulty in "recognizing the options to navigate the workplace" [64]. Men face these same structures but are much more likely to have a mentor or champion to help them negotiate their path. Women report that female mentors are scarce [65] and older males seem reluctant to "pal around" with younger women because of concerns of sexual inappropriateness [38]; unfortunately, the recent #MeToo movement is unlikely to make this easier for women engineers. The management literature has also identified the challenges women face if their mentors are male [66], even while revealing that female mentors can be less effective because they tend to be less well-connected to the power centers of the organization [67].

In their original SET study, Hewlett and co-workers introduced the idea of a "diving catch" culture in which only a risk-taking mentality was valued; this idea has not been echoed as often in subsequent engineering literature (*e.g.*, [60]). However, in a follow-up study, Hewlett and coworkers replaced this idea with a new barrier – "difficulty with executive presence." Women reported discouragement in progressing toward leadership roles because they found the desired leadership attributes ("executive presence") either hard to determine or to achieve, and effective mentors or sponsors were not available to help bridge the gap. This could in fact be a cross-over of a chilly climate, where unconscious bias against women in leadership bleeds over into lack of support for women to attain leadership roles. The same study reported that 46% of women in SET "believe senior management more readily sees men as 'leadership material'" and 23% agree that "a female would never get a top position at my company, no matter how able or well performing" [62]. Regardless of whether the source is gender bias or otherwise, the same sentiment was echoed among high-tech workers, where a key concern of women employees was "failures to strategically and objectively identify and develop talent" [51].

One result of these stalled career paths is that frustrated women leave the engineering workforce. In a quantitative study comparing mid-to-late career men's and women's career exit rates from STEM [43], dissatisfaction with pay and promotion was identified as the single determining reason for women's higher exit rates. A qualitative study of mid-career women in engineering [59] and subsequent quantitative study of women engineers [68] determined that lack of pay or promotion opportunities explained the departure of most women from engineering. In a quantitative study of engineers, men were most likely to mention "pay and promotion opportunities" as a reason for leaving engineering (31%); women also mentioned this although less frequently (15%) [36]. Without an accompanying qualitative study, it is difficult to understand if men and women were both leaving because of a *lack* of opportunities within engineering, or because of even more attractive opportunities elsewhere.

Extreme work pressure has also been identified as a feature of the engineering workplace which contributes to the departure of women. Often, extreme work pressure describes an experience of the demand for long hours with 24-7 availability and too-short deadlines [38]. This is not something experienced only by women engineers; a qualitative study of engineers from the millennial generation (those who entered the workforce after the year 2000) identified this as the most important concern of men and second-most important for women [60]. Beyond general work pressures, this category of barrier is often associated with how well engineering careers facilitate a work-life balance that is supportive of family responsibilities. A quantitative study concluded that it was "empathic support from their managers for their work-life roles … which serve[d] to characterize and catalyze the persistence and attrition decisions of women engineers" [69]. However, while family-supportive policies are appreciated (by men *and* women), it seems to be a common and convenient myth, often used to dismiss the significance of the higher engineering career exit rate of women compared to men, that women are choosing to leave engineering in order to stay at home and raise children. Quantitative studies have shown that when women leave engineering they are most often moving to a different career [37], [43], not leaving the workforce.

While most research focuses on the aspects of the engineering culture that force women out of careers, some work has identified personal characteristics that tend to differ between women engineering graduates who do or do not persist in engineering careers. One concept that bridges this gap is the idea of pro-social motivation [70]. There is some evidence that women are likely to be interested in work that is seen as useful or helpful to society or other people and thus if engineering workplaces could better present themselves as accomplishing this type of work, women would be more attracted to it or more inclined to persist [61], [71].

Engineering self-efficacy and self-identity are two personal constructs that might play a role in whether any individual woman persists in engineering. Self-efficacy is a construct that measures a person's belief in her abilities to be successful in a particular area or endeavor (e.g., engineering work) [72]. Engineering identity is the idea that a person self-identifies as an engineer and that this becomes an important part of her self-concept; a woman with a strong engineering identity will associate herself with engineers as peers and see that their own interests and personality are consistent with their idea of an engineer [61], [73]–[75]. Both concepts have been determined to be important for persistence among engineering *student* populations. A handful of qualitative studies have indicated that both engineering self-efficacy and identity are associated with greater engineering workforce persistence [61], [64].

Interest in engineering is a personal factor that can be more complicated than it might seem. It seems quite expected that some people's interests change over time and this might lead, quite rightly, to a career change, whether early or later in the career pathway. Some women never work in engineering after earning their degree; in one study 30% of these women said it was because they were no longer interested in engineering, or were more interested elsewhere [57]. A different quantitative study of engineers discovered that the most common reason self-reported by *both* men (33%) and women (47%) for *leaving* engineering careers was "to pursue more interesting work" [76]. A later study found similar results: "changes in career or professional interests" was the most common reason self-reported by women (26%) and also given by 20% of men [36]. However, there is not much evidence that lack of interest would fully explain the higher exit rate of women compared to men. A qualitative study reported that both men and women displayed a strong intrinsic interest in engineering work [77], but pointed out that intrinsic interests can be diminished over time as a result of the physical and social environment. Thus, a chilly or hostile climate could be intertwined in complex ways with career exits blamed simply on "change of interest." Further, a qualitative study comparing men and women engineers [78] identified that the different particular aspects of engineering that were interesting were not quite the same between men and women, and finding an appropriate *job* match could be important to long-term *career* persistence in engineering.

Women in the Engineering Workplace (Academia)

Women faculty members have a place in academic universities in the United States and are without question a privileged elite group of highly educated professionals [79]. Nonetheless, the number of women faculty members represented in all professorial ranks of STEM fields remain disproportionately low, despite women earning 57% of all bachelor's degrees and half of all science and engineering (S&E) bachelor's degrees [80], [81]. Women received 21.3% of all engineering bachelor's degrees in 2017 [80]. For advanced engineering degrees, women earned 25.7% of engineering master's degrees and 23.5% of engineering doctoral degrees in 2017 [80]. The percentage of women awarded doctoral degrees has varied widely by engineering discipline with mechanical engineering, computer science and electrical engineering accounting for the smaller percentages of degrees awarded. In 2017, 13.7% of all bachelor's degrees; 23.3% of master's degrees; and 19% of doctoral degrees were awarded to women in electrical engineering [80].

Percentages for women faculty members in tenure positions parallel percentages for degree recipients. In a 2005-2006 report by the American Association of University Professors (AAUP), women faculty members held 31% of all tenure positions at doctoral universities [82]; however, only 12.5% of women faculty members in STEM were tenured faculty in US higher education institutions [83], [84]. The biggest gap remains in tenured positions at research universities, where men outnumber women by 2.3 to 1. At bachelor's and master's institutions, the ratio changes to 1.5 men to 1 woman [85]. However, women outnumber men in tenured ranks at two-year colleges. In a 2017 report by the American Society for Engineering Education

(ASEE), Yoder [80] found the mean percentage of women tenured/tenure-track faculty in all engineering disciplines was 16.9%, though the range was quite broad across the disciplines (as high as 26.9% in environmental engineering but only 11.2% in aerospace engineering). Across all engineering disciplines, women faculty were better-represented in lower academic ranks (associate professor 19.5% and assistant professor 24.3%, respectively). Although women are under-represented among engineering faculty, they are not the only under-represented minority group. Of all tenured/tenure-track engineering faculty in the U.S., only 2.3% were African-American and 3.9% were Hispanic, and 27.9% were Asian [80]. The percentage of women faculty represented in these ethnicities are of course substantially lower.

As highly educated professionals, women faculty members in engineering are outnumbered by their male colleagues, are concentrated in the lower academic ranks, and are paid less than their male colleagues- a trend that had continued since the 1960s [82], [84], [86]–[88]. When compared with men, women faculty members advance more slowly than their male colleagues and rarely attain the highest rank in academia [89], [90]. This is particularly the case for women faculty members in engineering.

The gender disparity, concentration in the lower academic ranks, advancement through the academic ranks, and salary differentials suggests the disproportionate representation may be attributed to other factors in the educational environment. In 2001, the National Science Foundation (NSF) created the ADVANCE program to address issues of culture and structure that may adversely affect women faculty members and thereby increase the representation and advancement of women in engineering [91] (National Science Foundation, 2018). ADVANCE places emphasis on improving the institutional climate, recruitment and retention of women in STEM, thereby contributing to the development of a more diverse science and engineering workforce [91], [92]. The ADVANCE program has made important strides in diversifying the engineering workforce and encouraging higher education institutions to examine STEM cultures and institutional structures, but progress has been slow in achieving parity in the professorial ranks. The multifaceted approach utilized by ADVANCE addresses aspects of the STEM academic culture and institutional transformation but does not appear to reach into departments to address issues related to department structure and climate and how they affect female faculty members and administrators [91]. Addressing only the macro (institutional) climate overlooks the micro (departmental).

Over the last thirty years, researchers have attempted to understand the underrepresentation of women faculty members in STEM at the macro (institutional) level but fewer researchers have explored individual STEM (micro) departments. Attention to the institutional setting does not account for the environment in the department level that contributes to different experiences for men and women. Within engineering departments, the division of labor in activities, networking and collaboration, and the overall perception of women's abilities are among the contributing factors to gender-differentiated experiences and consequently, the underrepresentation of women in engineering faculty [93].

Research currently in progress examines experiences with department climate and the promotion and tenure process for women faculty members at five electrical engineering (EE) departments. Electrical engineering, which is one of the largest disciplines overall in the workforce, but which has among the lowest representation of women, makes a good case study for departmental microclimates. Four primary findings emerged from this study. First, women faculty members in EE experience a different structuring of activities (teaching, research and service) than men, with a higher percentage of time spent on service. The imbalance inhibits women from focusing on the activities that are crucial for promotion and tenure. Second from this research, some women faculty members in EE experience a lack of networking and mentoring which contributes to a lack of information [94]. In order to succeed, they have to be extroverted to force the interaction with a colleague. Those who are introverted do not succeed and are more likely to leave the department. A third finding is there is gender bias in the hiring process. Departments displayed closer scrutiny of a woman's academic vitae and in the interview process, female candidates were more heavily scrutinized than male candidates. Together, these caused difficulty in arriving at consensus for hiring decisions.

The fourth finding is a level of discrimination and verbal and sexual harassment that exists from male colleagues [94]. In examination of climate studies involving 432 faculty members at ADVANCE institutions, Bilimoria, Joy and Liang found, when compared to men, academic women in science and engineering perceived the departmental climate at their universities "as more disrespectful, non-collegial, sexist, individualistic, competitive, non-supportive, intolerant of diversity, and non-egalitarian." Their findings suggest that the negative departmental climate experienced by women faculty members in STEM is not isolated to one institutional type but is consistent across several types of institutions [95]. Though prevalent on the institutional level, the study by Settles [96] found sexual harassment and sex-based mistreatment exists in university settings and may be occurring in other male-dominated departments where women faculty members are the minority. Women faculty members face difficult situations, especially if their colleagues vote on the cases for tenure, but the #MeToo movement has empowered women faculty members to come forward to tell their stories and chronicle their experiences.

Disparities in gender representation across academic ranks in the engineering professoriate deserve further exploration. A better understanding of these disparities may be achieved by illuminating the experiences of women faculty members in individual engineering departments. To understand the difficulties of women faculty members at the departmental level, new initiatives should be informed by current research about the effects of department climate and the hiring, promotion and tenure process on women faculty members in STEM and, in particular, engineering departments.

Theoretical Frameworks for Engineering Workforce Research

Research on the engineering workforce should ideally be done within theoretical frameworks. A theory is testable and makes predictions that should apply in multiple settings; therefore, it is possible to test theories from other areas of human-subject research to find applications with women engineers. The theory that is selected will guide the selection and definition of important constructs and variables that should be explored. Many different theoretical frameworks have been successfully employed in past engineering workforce literature; some examples are presented here. Many workforce studies draw successfully on work in career and counseling psychology. Social cognitive career theory (SCCT) [97]–[100] seeks to describe relationships between academic and career interests, choices, and successes and it therefore has been used in studying student (*e.g.,* [101]) as well as workforce populations (*e.g.,* [68], [102]). Motivation theories are also well-applied for studying engineers; these consider what motivates people to act in a certain way (see [103] for an overview of motivation theory in engineering education research). One such motivation theory is expectancy theory [104], [105], which “assumes that behavior results from conscious choices among alternatives whose purpose it is to maximize pleasure and minimize pain” [106]. Expectancy theory has also been applied to engineering student (*e.g.*, [107]) and workforce populations (*e.g.,* [108]). Self-determination theory (SDT) ([109], [110]) posits that people are motivated for something when all three of their universal human needs (autonomy, competence, relatedness) are met; examples in the engineering workforce literature include [111] and [78]. Belongingness theory [112], [113] posits that humans are motivated by a need for closeness and social belonging. Gender theories are useful in providing a lens for women’s workforce experiences. A review of feminist theories in engineering education journals provides a useful starting point [114]; a “meta-analysis of feminist theories of the gendered politics of science and technology” was developed into a gender theory specific to women in SET [115]. While not exhaustive, this listing provides engineering workforce researchers a starting point for thinking about theoretical frameworks. Borrego’s [116] discussion of challenges that researchers trained in traditional STEM backgrounds might have with theoretical frameworks is a useful reference, as is a conceptual framework guidebook for engineering education researchers [117].

Methods [118]

By far, the most common instruments used to study women in the engineering workplace are surveys and interviews. The use of surveys is typically but not always a part of a quantitative research design that uses numerical data to address a research question or hypothesis across a relatively large sample population (*e.g.,* more than 100 participants). In general, surveys and quantitative methods address broader issues which provide generalizability to the data and often answer questions that begin with, “How?” Interviews, on the other hand, involve much smaller sample sizes (typically less than 50) and use qualitative methods to elicit deeper explorations and explanations of research questions that tend to begin with “Why?” or “What?” While a complete discussion of research methods is outside the scope of this paper, a brief description of each of the major types of methods (quantitative, qualitative, mixed methods) is provided next, in the context of studying individuals in the workplace. For an in-depth treatment of the three types of research methods, the reader is referred to a recently published text by Creswell & Creswell [118].

Quantitative methods [118], [119]

Quantitative research methods in education and social science collect numerical data and analyze them using statistics or other mathematical techniques. Some numerical data, such as age, income, and length of time in the workforce, may be naturally occurring and can be used without further processing for subsequent quantitative analyses. Most numerical data gathered via survey, however, are not naturally numerical. Some data can be made numerical through the creation of categorical variables from that data. For example, father’s level of education might be converted to a numerical variable as 1 = high school diploma, 2 = some college but no degree, and so on. Other data, particularly that which requires an individual to self-report an impression or an opinion, may be collected via a Likert scale. For example, a 5-point Likert scale may be used to assess how much an individual agrees with a statement or belief by assigning a score of 1 when the individual “strongly disagrees” and a score of 5 when the individual “strongly agrees”, with scores in between 1 and 5 providing options between these two extremes. 5-point Likert scales are the most commonly used in survey research because 7-point scales demonstrate greater response style bias [120]. Some argue that binary responses (yes or no) and 3-point scales are good enough and have the added advantage of shorter survey completion times [121], [120].

Measures, scales, or subscales may consist of a single Likert scale item or multiple items. While multiple-item scales have historically been the preferred choice in survey research, there are times when single items scales are the better choice [122]. For data that is not pre-coded (*i.e.*, assigned numerical values on the survey itself) into Likert-scale or other rating scales, post-coding into numerical quantities is often used prior to certain analyses. For instance, gender may be collected as male or female, but coded as 0 (male) and 1 (female) prior to analysis. *Dummy* coding uses only 0's and 1's to express categories as numbers while *effect* coding uses -1's, 0's, and 1's. In both cases, *k-1* variables are needed to transform *k* groups or categories into numerical data. While there is often not much difference between using *dummy* coding or *effect* coding, when interactions between variables are important or when more complicated comparisons between variables are needed , effect coding is more powerful and provides more intuitive interpretation of results.

More often than not, *effect* or *dummy* coded variables are *nominal* variables because there is no measure of distance between one value of the variable and the next value. For example, if gender is *effect* coded as -1 = male and 1 = female, being female is not inherently larger than being male. The distance between being male and female has no real meaning numerically and the gender variable is therefore *nominal*. In contrast, an *ordinal* variable does imply that there is a ranking to the numerical values of a variable. Most Likert-scale items provide ordinal data, although under some conditions, multiple Likert-scale measures can be treated as interval data. For instance, in a 5-point Likert scale that ranges from strongly disagree (1) to strongly agree (5), a score of 2 is stronger or higher (more agreeable) than a score of 1. While unlike *nominal* variables, *ordinal* variables provide rank, they do not provide distance. The distance between a score of 4 and 5 on a Likert scale has no inherent, predictable, or distinct meaning. An *interval* variable does provide a predictable distance between adjacent scores. For example, age is an *interval* variable. The difference between 24 and 25 is one year of time just as the difference between 29 and 30 represents the same distance in time. A fourth type of variable, the *ratio* variable, provides all the characteristics of an *interval* variable but also gives a special meaning to 0. With a *ratio* variable, the value of 0 represents a complete absence of what is being measured. For example, time on job can be a *ratio* variable as 0 represents the complete absence of the job, while 4 months is exactly twice two months on the job.

Demographic information is an important part of workforce studies of all kinds. Most of this data is or can be numerical and are often used to understand differences between subgroups in a study population. Demographic data typically include gender and race but can be expanded to include employment status, age, income, and other indicators which are relevant to the research questions or hypotheses defined in a quantitative study. Basic demographic questions which are applicable to workplace studies including typical phrasing of questions and response options are provided in Table 1.

Table 1: Basic Demographic Questions [124],[125]

Question	Response Options	Question	Response Options
What is your gender?	• Male • Female • Other (please specify)	What is your marital status?	• Single (never married) • Married, or in a domestic partnership • Widowed • Divorced • Separated
Are you of Hispanic, Latino, or Spanish origin?	• Yes • No	What is your age?	• 18-24 years old • 25-34 years old • 35-44 years old • 45-54 years old • 55-64 years old • Over 65 years old
What is your race?	• African American or Black • American Indian or Alaskan Native • Asian • Native Hawaiian or other Pacific Islander • From multiple races • Other race (please specify)	What is your annual household income?	• Less than $20,000 • $20,000 to $49,999 • $50,000 to $99,999 • $100,000 to $124,999 • $125,000 to $149,999 • $150,000 to $174,999 • $175,000 to $199,999 • Over $200,000
What is your marital status?	• Single (never married) • Married, or in a domestic partnership • Widowed • Divorced • Separated	What is your current employment status?	• Employed full time (40 or more hours/week) • Employed part time (up to 39 hours/week) • Unemployed, currently looking for work • Unemployed, not currently looking for work • Student • Retired • Homemaker • Self-employed • Unable to work

In addition to basic demographics, engineering workplace studies may also require additional information regarding the discipline in which an individual is educated and works. Sample questions for gathering this kind of information are provided in Table 2. Although not included in Table 2, additional questions may be added to include job title or position within the specified discipline and industry.

Table 2: Examples of Discipline Specific Demographic Questions

Question	**Response Options**
What is the highest degree or level of school you have completed?	• Bachelor's degree (e.g. BA, BS) in engineering • Bachelor's degree (e.g. BA, BS) outside of engineering • Master's degree (e.g. MA, MS) in engineering • Master's degree (e.g. MA, MS, MEd) outside of engineering • Professional degree (e.g. MD, DDS, DVM) • Doctorate (PhD) in engineering • Doctorate (e.g. PhD, EdD, JD) outside of engineering
In which field of engineering did you receive your undergraduate degree?	• Bioengineering • Chemical Engineering • Civil or Environmental Engineering • Electrical or Computer Engineering • Industrial Engineering • Mechanical Engineering • Other (please specify)
Which field of engineering best describes the work associated with your present workplace?	• Bioengineering • Chemical Engineering • Civil or Environmental Engineering • Electrical or Computer Engineering • Industrial Engineering • Mechanical Engineering • Other (please specify) • I am not working in engineering

In addition to demographics, surveys designed for the workplace often measure dimensions related to both work-related and non-work factors that are relevant to specific research questions using a wide range of Likert scale questions. Some constructs, such as those measured by the Job Content questionnaire [126] are copyrighted and available only with permission and for a fee while others, such as engagement and career commitment scales, are available for free [127].

Although a full overview of relevant scales and measures is beyond the scope of this paper, a selection of measures and sample items relevant to workplace studies is summarized in Table 3.

Table 3: Work and Non-Work Factors used in Engineering Workplace Studies

Construct/Scale	Sample Item	Complete List of Items
Autonomy	I feel like I can make a lot of inputs to deciding how my job gets done.	Deci & Ryan [128]
Burnout	I feel emotionally drained from my work.	Mind Garden [129]
Career Commitment	I would recommend a career in engineering to others.	Buse 2011 [127]
Competence	Most days I feel a sense of accomplishment from working	Deci & Ryan [128]
Developmental Experiences	In the positions I have held at <name of company>, I have often been assigned projects that have enabled me to develop and strengthen new skills.	Wayne et al. 1997 [130]
Engagement	When I am working, I forget everything else around me.	
Hope	There are lots of ways around any problems I am facing now.	Buse 2011 [127]
Identity	Knowing that I continue to be essentially the same inside even though life changes is important to me.	
Coworker Social Support	My coworkers are interested in me.	
Decision Authority	I have little decision freedom in my job	Karasek et al. 1998 [131]
Psychological Job Demands	I have enough time to do my job.	JCQ Center Global [126]
Job Insecurity	My skills are valuable in my present position.	
Skill Discretion	My job requires that I learn new things	

Supervisor Social Support	I have a hostile supervisor	
Job Satisfaction	I feel good about working at this company.	McDonald & McIntyre 1997 [132]
Leader-Member Exchange	I usually know where I stand with my manager	Wayne et al. 1997 [130]
Optimism	I usually count on good things happening to me	Buse 2011 [127]
Organizational Commitment (Affective)	I really feel as if this organization's problems are my own	Allen & Meyer 1990 [133]
Organizational Commitment (Continuance)	Too much in my life would be disrupted if I decided I wanted to leave my organization now	
Organizational Commitment (Normative)	I do not believe that a person must always be loyal to his or her organization	
Perceived Organizational Support	<Name of company> management cares about my general satisfaction at work.	Wayne et al. 1997 [130]
Relatedness	People at work care about me	Deci & Ryan [128]
Self-Efficacy	Thanks to my resourcefulness, I know how to handle unforeseen situations.	Buse 2011 [127]
Turnover Intentions	I often think of leaving the organization	Liu 2005 [134]
Work-Family Conflict	My family/friends dislike how often I am preoccupied with my work while I am at home.	Gutek et al. 1991 [135]

Using a combination of demographic and Likert-scale items and sometimes, short answer and alternative style questions, the quantitative analysis of survey data is well suited to answering certain research questions, particularly those that start with: How? How much? How many? How different? How often? Some examples of these types of research questions in the context of studying the engineering workplace include:

- How do the earnings of women in the engineering workplace differ from those of men?
- How different is the percentage of women who remain in engineering after graduating with a bachelor's degree in engineering compared to the men who remain? [136]
- How many women experience discrimination or sexual harassment while working as engineers? [137]
- How often do women faculty speak with colleagues in home units about research compared to men? [138]
- How are women who persist in an engineering career different from women who leave such careers in terms of turnover intentions, occupational commitment, self-confidence or outcome expectations? [139]

Quantitative methods are also well suited for studies that seek to understand relationships between variables and how one or more independent variables predict a dependent variable. These studies may be cross-sectional (evaluating one point in time) or longitudinal (evaluating two or more different points in time). For example:

- How do work family conflict, work environment, and non-work factors predict burnout? [140]
- Do hope, engagement, self-efficacy, optimism, or identity predict career commitment among women engineers in the workplace? [127]

Finally, quantitative methods are also well matched to research driven by a specific hypothesis. For instance:

- Attitudes toward the job will be negatively related to turnover intentions among women in the engineering workforce [141].
- Self-efficacy will be positively associated with job attitudes among women in engineering [141].

Statistics are typically used in answering research questions or to test hypotheses of the types discussed above. In most statistical analyses, there are certain target criteria that must be met in order for the results of the test to be considered accurate. For example, a statistical test that reports a *significance* level within $p = 0.05$ indicates with 95% confidence that two populations are different with regard to a particular outcome. For example, if an analysis of the difference in self-efficacy between men and women results in a significance level of 0.05, this implies that there is only a 5% chance that there is really no difference between the levels of self-efficacy between men and women, and a 95% chance that the difference measured does exist. The 0.05 or 5% criteria is the standard level in academic research used to reject the null hypothesis, which presumes no difference in the value of a variable between two groups or populations.

Another important criterion in statistical analysis is the statistical *power*. Whereas the significance level considers the type 1 error (i.e. the likelihood of rejecting the null hypothesis when it is in fact true), the statistical *power* considers type 2 error (i.e. concluding that there is no difference or effect between two populations or groups when in fact there is one). The statistical *power* is given as (1 – Type 2 error) and provides the likelihood that a statistical test will detect a difference between two groups when there actually is one to be detected. The standard criterion for statistical *power* is 0.8 [142]. In the previous example of self-efficacy, a statistical power of

0.8 would mean that there is an 80% likelihood that self-efficacy between men and women is indeed different. Or, 80% of the time, statistical tests would detect a difference in self-efficacy and 20% of the time, these same statistical tests would not detect the difference. The statistical *power* criterion ensures that there is sufficient data collected to detect more subtle differences between groups within the data.

In statistical analyses of survey data, *effect size* is also important. In plain English, *effect size* measures the strength of the relationship between two variables. The greater the *effect size*, the stronger the difference between two variables. The Pearson correlation is a popular means of evaluating effect size with a Pearson correlation (r) of around 0.1 representing a low effect size, 0.3 a medium effect size, and greater than 0.5 representing a larger effect size [142], [143]. For example, if job satisfaction for men demonstrates a Pearson correlation with job satisfaction for women of 0.15, then it is likely that the difference in job satisfaction between genders is not particularly noteworthy. In combination, the desired *significance* level, *effect size*, and statistical *power* provide not only the results of a statistical analysis but insight into how accurately they represent the larger population from which a sample is taken.

At the front-end of quantitative research, the way in which the data is initially sampled can also hinder the validity of the results. *Random sampling* is considered the best way to ensure accuracy and generalizability of results and ensures that any individual within a particular population (e.g. workplace or category of workplaces) is equally likely to be included in a study. In practice, however, simple *random sampling* of individuals in the workplace is nearly impossible due to the availability of contact information from individuals in a study population and the difficulty in identifying populations in the workplace. Non-random sampling is therefore to be expected in workplace surveys and may include data only from those who volunteer or agree to participate, or may involve other common forms of sampling to acquire a target sample size [144]:

- *Snowball sampling*: relies on one participant to identify other participants in a population.
- *Convenience sampling*: an opportunistic means to recruit participants such as a captive audience in a conference.
- *Quota sampling*: selects a fixed number of people from each group of interest.
- *Haphazard sampling*: uses multiple sampling techniques in situations where recruiting sufficient numbers of individuals is particularly difficult. Such difficulty is often the case in workplace studies.

Survey research also introduces a strong likelihood of response bias, which must also be considered in interpreting the results. Participants may exhibit *acquiescence*, or "yea-saying" bias, where they have a tendency to agree with all statements of a certain type. Likewise, *"nay-saying"* participants may have a tendency to disagree with certain categories of statements. Although *acquiescence* bias can be minimized by using a combination of negatively worded (reverse coded) and positively worded questions or statements, awareness of certain populations to tend toward the positive or the negative should always be kept in mind when interpreting results. Related to *acquiescence* bias is *social desirability*, where participants may feel they are expected to respond in certain ways. For example, some women surveyed in the workplace may feel that it is undesirable to admit that they lack confidence in their work and may therefore over-report their confidence in a survey [145]. Overcoming *social desirability* bias is difficult but maximizing anonymity and confidentiality in surveys and randomizing the order of survey items can help to overcome this form of bias. Although not always realistic, using proxy subjects (i.e. asking someone who knows the participant to answer the survey based on their perceptions of an individual) can also serve to reduce social desirability bias. Complementing surveys with follow-up interviews is also an effective and practical way to understand and overcome this type of bias.

In summary, while many may feel that numerical data provides the most accurate and objective picture of what's going on in a particular environment, the reality is that quantitative research is just as vulnerable to distortion, error, and bias as qualitative approaches to research design. Research results must be interpreted with as much caution as any other types of analysis. And although quantitative methods can be applied to a wide range of research questions and hypotheses, there are certain types of problems to which quantitative methods are ill-suited. While quantitative methods provide breadth across large study populations and numbers of subjects, they generally do not provide adequate depth to explore why certain relationships and differences emerge from numerical data. They generally cannot provide insight into underlying complexities and meanings of results and circumstances, nor are they useful for developing hypotheses and research questions. In workplace studies in particular, sampling and response bias as well as inadequate sample sizes or difficult in identifying sample populations may also confound the accuracy of results obtained using quantitative methods. Thus, to complement quantitative methods and address some of these limitations, qualitative methods that use interviews, case studies, ethnographic approaches, and other complex data collection techniques may be needed to best understand what goes on in the engineering workplace.

Qualitive Methods [118], [146], [147]

At its most basic level, the primary underlying difference between quantitative and qualitative research methods is that while quantitative methods seek to confirm (a hypothesis or answer to a research question), qualitative methods seek to explore (i.e. cast the net). This fundamental difference between the goals of the qualitative and quantitative methods lead to other differences in structure, questions, data, and study design:

- Quantitative methods tend to quantify variation in the data while qualitative methods describe it.
- Quantitative methods predict causal relationships while qualitative methods explain them.
- Quantitative methods use primarily close-ended questions while qualitative methods use more open-ended questions.
- Quantitative methods collect numerical data while qualitative methods collect primarily textual data from field notes, audio recordings, or video.
- Questions asked using quantitative methods are usually not influenced by participant responses, while questions used in qualitative methods are usually adjusted or expanded based on such responses.
- Quantitative methods tend to have a more rigid, stable design structure while qualitative methods are more semi-structured and flexible.

Qualitative methods tend to produce data which are not only more meaningful to a study participant but are also richer, deeper, and more complex for the researcher. This is not to say that quantitative methods produce data of lesser value but rather that qualitative methods often complement quantitative methods by trading breadth for depth. In addition to providing substantially more information per study participant, qualitative methods also require more effort per participant in analysis and interpretation. Because of the greater effort and time it takes to collect qualitative data and the corresponding difficulty in recruiting subjects, qualitative data sample sizes tend to be substantially smaller than quantitative sample sizes. However, rather than relying on significance, power, and effect size to be valid, sample sizes in qualitative research designs rely on data saturation. Data saturation is the point at which study participants begin to say the same thing or touch on the same themes, thus making further data collection and recruitment of additional subjects of limited value. Since data saturation can occur with two subjects or with two hundred, it is almost impossible to predict in advance how large a study should be to be valid or to compare one study with another in terms of the goodness of sample size.

The three most common instruments used to collect data in qualitative research designs are participant observation (e.g., observing an engineer at work), interviews, and focus groups. *Observations* are made using guidelines that are predefined by the researcher to support the research question or hypotheses. Observations are typically conducted in similar situations (e.g., design reviews, staff meetings) from participant to participant to ensure consistency in the amount and type of insight gained from them. Interviews are one-on-one conversations while focus groups involve multiple individuals. *Interviews* are one-on-one interactions between the researcher and study participant are best suited to sensitive topics where participants may be reluctant to offer information in a focus group setting. Discussion of sexual harassment in the workplace is one topic that may be better suited to interviews rather than focus groups to provide the interviewee with a greater sense of safety and confidentially in sharing sensitive information. *Focus groups,* on the other hand, are well suited to converging toward the broader issues that may affect a certain population of people. Focus groups are also valuable to complement interviews to understand the expectations and behavior that guide certain groups of people (e.g., the cultural norms). In gender-based workplace studies, a combination of focus groups and interviews can be valuable to not only understand a woman engineer’s experience in a particular workplace but also to elicit what the expectations are for how she is expected to deal with any difficulties and challenges she encounters in the workplace. Of these three research instruments, interviews are often best suited to workplace studies because participant observations in the workplace are typically difficult to coordinate, and focus groups of similar populations (e.g., multiple individuals in the same workplace) face considerable scheduling difficulties.

Any one or a combination of these types of instruments can be used in a qualitative study but should be well-matched to the research design itself. The major qualitative research designs include [147]:

- *Ethnography* involves immersion in an individual’s real-life experience to fully understand what the individual sees, feels, and thinks as part of that experience. Ethnographic research typically involves a great deal of participant observation, substantial field notes, and is of long duration. For example, engineers at three different companies were observed to identify and understand if a masculine culture, whether subtle or overt, made it easier for male engineers to fit in than female engineers [148]. While ethnography offers a richness of understanding and complexity of data that is not available via other methods, whether qualitative or quantitative, scheduling difficulty and availability as well as other conflicts with the workplace setting often make this technique impractical for workplace studies.

- *Narratives* are similar to ethnography in that they seek to build the big picture around an individual's experience, but they seek to do so by developing a story around the individual. Multiple interviews over a moderate to long time period are typically conducted to build the narrative, whether or not the story is told chronologically. Other documents, such as resumes and transcripts, may supplement the story emerging from the interviews. An example of a narrative developed in the engineering workplace is one for two very different professional identities developed of female engineers, one that emphasizes women as being just as good as men engineers and one that establishes women as different as men in engineering [149]. While the narrative does not involve the potential conflicts of interest or awkwardness associated with being observed in the workplace, it still has many of the same scheduling and longitudinal and extensive time commitment challenges that ethnography does.
- *Case studies* are similar to narratives in that they capture a larger picture regarding an experience, but case studies tend to focus on entities that extend beyond a single individual (e.g., a corporation or other organization, an event, etc.). Like narratives, case studies can use more than one data source and multiple types of data and can explore, explain, or describe an event or milestone. The level of difficulty involved in developing a case study in the workplace varies by the type of documents collected and interviews/focus groups conducted to achieve the goal of the case study.
- *Phenomenological* studies seek to describe a certain observable event and in the context of studying individuals in the workplace, rely heavily on interviews with individuals to explain the targeted phenomena. For instance, one workplace study relied on interviews to describe the challenges (phenomena) that minority women faced in transitioning from college to being employed in engineering [150]. This study also sought to explain some of those challenges in terms of what types of external supports helped, hindered, or made little difference in the transition. At the point where the study sought to explain transitional challenges, it transitioned into more of a grounded theory approach to the questions at hand.
- *Grounded theory* designs, rather than describing an event as phenomenological studies do, seeks to explain the event. Interviews, focus groups, and other documents are used to code possible explanations for an event and theory is developed based on those codes to explain the event. Theories emerging from grounded theory studies can then be tested using quantitative studies to evaluate the generalizability of the theory to a broader population. For example, interviews of female Australian civil engineers sought to explain why some women remained in engineering and some left. Women who remained had taken intentional steps toward finding interesting and challenging work in inclusive environments [151]. The emphasis on the "Why?" question made this study more a grounded theory approach than a phenomenological one.
- *Participatory action research* designs can mean slightly different things in different fields, but the unifying element is that the researchers and the study participants work to understand a problem or find a solution to a problem. This design is particularly well

suited to complicated problematic situations in which change for the better us urgently needed.

The qualitative research design guides the number and type of instruments used to collect data, the types of questions that are incorporated into the instruments (e.g. interview protocols, observation guidelines, etc.) and the progression of the data collection and analysis from start to finish. The resulting data (transcripts, field notes, audio recordings, etc.) can be approached from one of two different camps. It can be assessed *deductively*, whereby the research questions are used to group, categorize, and code the data based on a theoretical or conceptual foundation that guides the analysis. Or, the data can be evaluated *inductively* where no predefined groups or codes are available, but instead, the coding of the data and the interpretation of those codes emerge in multiple passes at the data. Through the course of multiple passes, a richer understanding of the data emerges as well as greater insight into the questions guiding the research.

In addition to the approach (deductive vs. inductive) and the nature of the research design (ethnographic, grounded theory, etc.), several data analysis techniques are available to organize and evaluate the data. If the end goal is classifying, tabulating, or classifying data, *content analysis* is an appropriate analysis procedure. In a workplace study, content analysis might be used to group what participants say into certain types of barriers to or promoters of workplace fulfillment. If the researchers have few specific expectations of the data and instead are trying to explore such data to its fullest, a *grounded theory* analysis may be more appropriate. *Grounded theory* analysis begins with a single case or small number of cases within a dataset to develop a hypothesis about the data. Subsequent data is then analyzed to see if the new case fits the hypothesis developed from the initial cases. If it does, it lends strength to the hypothesis and the researcher moves on to the next case. If it does not, the new data is either determined to be part of a separate population and set aside or the hypothesis (or statement) guiding the initial set of data is modified to incorporate the new data. In this way, new hypotheses or research questions that was not originally anticipated can emerge as a result of the data analysis process. In contract to content analysis which seeks results tables and grounded theory seeks new hypotheses, a *narrative analysis* searches for a story. Specifically, *narrative analysis* in qualitative research designs seeks to reformulate an individual's story into a story that embodies the research question or reflects confirmation of the research hypothesis. Venturing even further into the subtler aspects of qualitative data, *discourse analysis* focuses on the way things are said (or not said) rather than entirely on what is said. In *discourse analysis*, patterns of speech and expression then inform the research question and guide the interpretation of results. This form of analysis can be especially useful in situations where study participants may be choosing to withhold certain information or attempting to confirm to researcher's expectations, either positive or negative. While these four forms of analysis are not the only tools available for evaluating and interpreting data, they are common in workplace studies as they provide rich information that surveys cannot, both in what is said and unsaid.

Qualitative studies provide a richness of understanding individuals, experiences, and stories that quantitative analyses cannot. Unfortunately, the evolving and emerging nature of results in qualitative research designs and the lack of formal statistical significance in the results can often lead to underestimating the value of these methods. Fortunately, qualitative studies do not have to stand on their own. They can be used to guide, supplement, or otherwise complement quantitative studies using several options of mixed methods research designs.

Mixed Methods [118], [152]

True to their name, mixed research methods collect, analyze, and combine quantitative and qualitative data. The methods can be mixed during the same phase of the study (e.g. used concurrently) or they can be used in sequential phases of data collection or analysis. In mixed methods, priority is given to both forms of data, so that the strengths of each kind of data can be leveraged to answer complex research questions while minimizing the weaknesses that may arise in purely qualitative or purely quantitative research. In mixed methods research, the ability to generalize within large sample sizes inherent to quantitative research can be combined with the small sample sizes and accompanying detail and depth of qualitative research to greatly improve the overall understanding of a research problem or to explain why particular research hypotheses are rejected or confirmed. Although the ways in which quantitative and qualitative methods can be combined are many and varied, there are four major types of mixed methods research designs.

A *convergent parallel* design collects both quantitative and qualitative data at the same time. This approach provides complementary data to enable a more complete understanding of a research problem. One type of data serves to validate the other. Once both types of data are collected and analyzed, they are then compared or related to one another prior to interpretation. In the convergent parallel design, it is important to keep the two data analyses separate in order to avoid bias. During interpretation, the analysis results are examined for contradictions and confirmations as well as convergence and divergence between the two forms of data and their respective analyses. For example, in a workplace study, a survey regarding barriers that women face in engineering positions can provide a broad quantitative view of how often and how many barriers women face while interviews of a random sample of women in the survey pool can explore the nature and intensity of those barriers in greater depth.

Unlike the convergent parallel design, the *explanatory sequential design* uses the two primary methods of research design in sequence rather than in parallel. Quantitative methods are used first and are followed up by a qualitative research design that is designed based on the results of the quantitative study. Typically, but not always, the quantitative methods have first priority in this design. While the participants in the qualitative study should have also participated in the quantitative study, they are usually a smaller subset of the quantitative population. In a workplace context, an explanatory sequential design might involve a screening survey intended to identify women with certain characteristics (e.g. undergraduate degrees in a specific discipline, years past degree, etc.) and the qualitative portion would target participants with those preselected characteristics. Or, alternatively, the screening survey might be used to capture workplace characteristics, then analyzed to determine those which are most frequent, and subsequent qualitative study participants selected from the target populations determined from such analysis.

The *exploratory sequential design* in the mixed methods world is often called the instrument design phase in a large research project. Qualitative data is collected to understand or inform the quantitative study. For example, case studies of a small number of women working in academia could be used to support the development of hypotheses regarding the career pathways of women in the engineering academe. The generalizability (and prevalence) of these pathways could then be explored in a follow-up survey or other quantitative study.

And, finally, the *embedded design* involves the collection of quantitative data during a qualitative procedure or the collection of quantitative data during a qualitative procedure. Collection of the embedded or second data set can happen before, during, or after the collection of the first data set but the primary differences between this type of mixed methods design and the convergent parallel design are that in convergent parallel design, qualitative and quantitative data are conducted independently and in an embedded design, one method (quantitative or qualitative) typically collects a smaller amount of data and is nested (an integral part) within the other type of design. For instance, in a workplace setting, a researcher may survey a sample of working engineers to understand how prevalent certain known barriers to advancement are in their respective workplaces. But, if the researcher is not sure whether the survey covers all possible barriers in the workplace, he or she may include some open-ended questions which solicit additional barriers not explicitly mentioned in the close-ended survey questions. In the data analysis, a smaller number of additional barriers (obtained using qualitative methods) would be nested within a larger dataset regarding the prevalence of known barriers in the workplace.

Summary

Unlike engineering education research, where sample populations are often captive audiences and recruitment and response rates can be quite high, particularly with the correct incentives (e.g. extra credit, gift cards), studies of the engineering workplace are often hampered by recruitment difficulties. The #MeToo movement, by raising awareness to challenges that women face in the workplace, both those associated with sexual harassment and those associated with other hostile or chilly climate factors, may temporarily increase the number of women willing to come forward to share their perceptions and stories. Even so, the amount of time that women in the workplace have to commit to research studies and the accessibility to the workplace can be highly restricted. Contact information may also be hard to come by as many universities and higher education institutions are reluctant to release alumni lists for research studies. Using a snowball recruitment procedure, where one participant recruits one or more additional participants, can help to improve contact and access, but snowballing invariably introduces bias and reduces the random sampling of the study population.

Limitations in contacting and recruiting study participants as well as highly limited access to the workplace itself (due to intellectual property and other concerns) mean that interviews and surveys are likely to remain the preferred instruments of workplace research well into the future. While existing studies have largely used one or the other of these techniques, mixed methods studies show great promise in linking the “How?” questions to the “Why?” or “What?” questions in the same study so that greater insight can be gained in the overall knowledge base. Regardless, there are many opportunities for each type of research method to contribute to our overall understanding of gender issues in the engineering workplace, particularly in identifying effective means to reduce leaky pipelines in engineering careers, retain women, and increase overall gender parity and diversity.

Concluding Remarks

In conclusion, while there has certainly been substantial research activity in the area of women in the engineering workforce, many opportunities remain. One obvious area for contribution would be to more clearly sort out the distinctions between STEM, SET, S&E, and engineering. The frequent cross-application of findings has been practical, particularly as the field of study is still relatively new, but it may not always be most informative. Along a similar vein, there is potential for sorting out the influence of which types of engineering (disciplines or workplaces) present more normative male dominance, and how that might yield differential impacts for those women. Generational age is another factor that has perhaps not been as closely attended to as it should, although a few studies have begun to examine this question [60], [78]. Researchers still rely upon findings that may no longer apply to the newest women engineers of today. Finally, the issue of other under-represented minorities (URM) in engineering (including racial, ethnic, and sexual preference minorities), and particularly, intersectionality for URM women, has not been addressed in this paper, but is extremely important. Racial minority women make up less than 2% of the engineering workforce ([153]) which frankly makes them a difficult population to locate and study; this is likely why they tend to be somewhat overlooked in much of the current research. However, without efforts in this direction the cross-applicability of current research is really unknown. For an example of a qualitative study that has focused on the challenges and effective supports relevant to minority women, see [154].

In 1972, Title IX guaranteed legal access to an engineering education for all women. Forty-seven years later, those pioneering women have started and finished their engineering careers. While the U.S. has certainly made great strides over that time to increase women's full participation in engineering, the lost opportunities, both for individuals and for the nation as a whole, loom large. Further, the participation of other minority groups lags even farther behind, such that it is not really even known how they are faring. The need is great for deep and broad, theoretically framed research on the well-being of the engineering workforce.

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