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Women in Mechanical Engineering: Representation Trends in Education and the Workforce

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Abstract

While percentages of women employed in STEM fields in the United States has generally risen, albeit slowly, over the past several decades, the percentages of women employed in engineering fields specifically has increased at a glacial and stagnating pace. According to the Bureau of Labor Statistics, only 3% of practicing engineers were women in the 1970s compared to about 16% in 2023. There is slightly more growth in the percentages of women graduating with engineering degrees, with current numbers hovering around 24% for undergraduate and 26% for graduate students across all areas of engineering; however, this growth has plateaued in the past decade. Women make up fewer than 20% of graduates in Mechanical Engineering in both undergraduate and graduate degrees, a field historically associated with heavy industry, which may contribute to this disparity.

This paper aims to surface and explore aspects of these trends, laying the groundwork for a larger book project that will share the stories of women in the Mechanical Engineering department at the University of Michigan, Ann Arbor. We will summarize the trends of women in both the engineering workforce and in engineering academia. We will delve into the data for Mechanical Engineering relative to other fields and summarize reasons the percentages of women in Mechanical Engineering programs and occupations have stalled.

Introduction

Women are, and have consistently been, underrepresented in STEM fields in the United States [1]. This underrepresentation is particularly pronounced in engineering, where women have historically faced significant barriers to entry and advancement. According to the Bureau of Labor Statistics, only 3% of practicing engineers were women in the 1970s compared to approximately 16% in 2023 [2]. Figure 1 shows how noticeably engineering as a field has a greater gender disparity, with women consistently making up far less of the workforce, compared with other occupational domains. In education, there is growth in the percentages of women graduating with engineering degrees with current numbers hovering around 24% for undergraduate and 26% for graduate students across all areas of engineering, but the growth has plateaued in the past decade [3]. Women currently make up fewer than 20% of graduates in Mechanical Engineering (ME) at both undergraduate and graduate degrees [3].

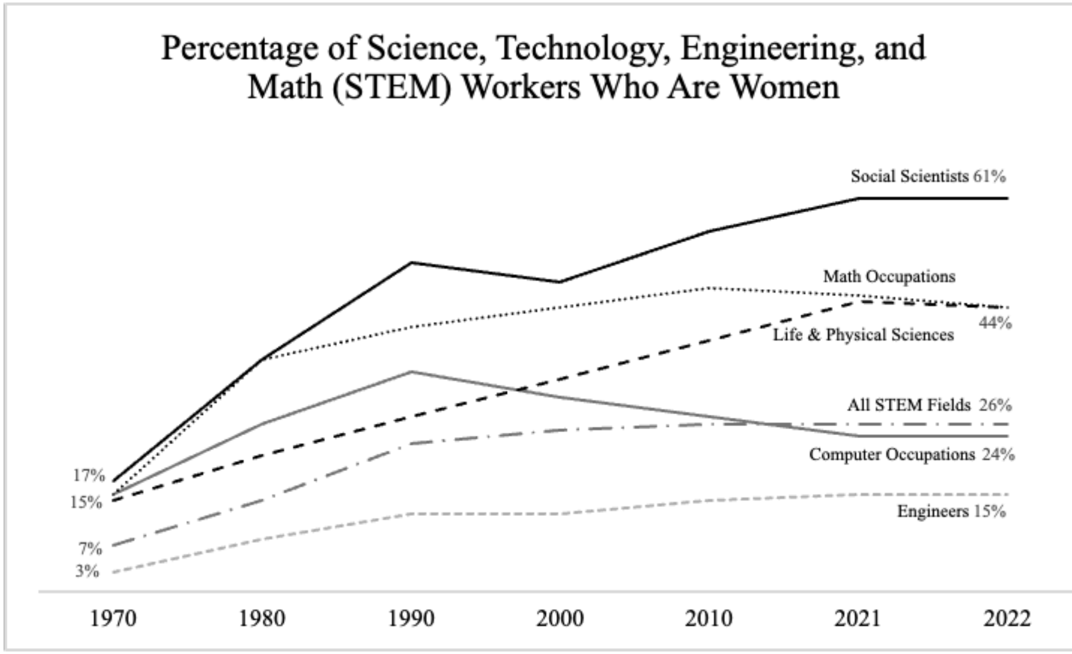

Fig. 1. Reproduced graphic from the U.S. Department of Labor using U.S. Census Bureau data [4].

This persistent gender gap in engineering has significant implications for innovation, economic competitiveness, and social equity. A lack of diverse perspectives in engineering can limit creativity and problem-solving, hindering the development of technologies that meet the needs of a diverse population. For example, the design of medical devices or automobile safety features may be less effective for women if engineers lack the body types and lived experiences of women. Furthermore, this lack of diversity also represents a missed opportunity to fully utilize the talent and potential of half the population. This paper focuses specifically on the representation of women in ME, a field that has historically been one of the most male-dominated within engineering. Possible reasons for this higher disparity include ME's historical association with heavy industrial processes and machinery, which may have created a perception of incompatibility for women, and a lack of female role models withing the field. By exploring trends in women's participation in ME education and the workforce, we aim to provide insights into the persistent challenges and potential pathways for increasing women's representation and success in this critical field. This analysis will serve as a foundational study, providing quantitative context for a larger book project that will delve into the lived experiences and stories of women in the ME department at the University of Michigan.

Literature Review: What drives the patterns and what needs to change?

For decades, scholars have been interested in understanding the patterns and drivers of gender disparities in the engineering workforce (e.g. [5], [6], [7], [8]). Extensive research has also examined factors that drive women to succeed in or leave these fields, often categorized into two main areas: factors connected with organizational context, culture, and climate, and factors related to individual attributes. For example, in a 1989 publication, sociologists Robinson and McIlwee researched women engineers in the workforce in aerospace engineering, electrical engineering, and mechanical engineering [7]. Based on interview data with women in these fields, the authors argue that the interaction of two key sets of variables impact the success of women in these firms. These variables are (1) sets of structural elements, like the degree to and ways in which engineers are valued in their organizations, and (2) "socialized gender attributes," like the relatively lower technical self-confidence and assertiveness of women engineers, which can also interact with both obvious and subtle harassment women engineers often experienced. Decades of research have highlighted two important drivers (which can interact) of the gender disparity of engineering academia and the workforce: the context of climate, cultures, policies, and procedures of organizations and person-based attributes like interest, abilities, and self-confidence.

The recognition of this disparity and the pursuit of effective strategies for recruiting, retaining, and promoting women in engineering – both in academic and professional contexts – are not recent endeavors. Groups formed to devote resources and energy towards tackling the issue. These include the Society of Women Engineers founded in 1950 [9], whose mission is broadly to empower women to achieve their full potential in careers as engineers and leaders, and the non-profit WEPAN, originally the Women in Engineering Program Advocates and now the Women in Engineering Proactive Network, which was founded in 1990 [10]. The NSF began funding major, evidenced-based organizational work to effect meaningful changes in the early 2000s [11]. Because of the decades of scholarly interest in addressing this disparity, much is already known about patterns of, drivers of, and potential solutions for improving the presence and experiences of women in engineering academia and the engineering workforce.

By the early 1990s, the need to formally document and address the multifaceted issues facing women in engineering was increasingly acknowledged. The inaugural issue of ASEE Prism was on the cutting edge of this as Senior Editor Jeff Meade decried the lack of women in academic engineering settings and outlined, based on discussions with women engineers, several reasons why this inequity exists: being specifically advised against going into engineering ("it's not ladylike"); a general lack of exposure to engineering in high school; having too few female role models in classes or in their families; lack of self-confidence; how men treat women in their classes (not well); and overall feelings of isolation [12].

At the national level, in 1991, the Committee on Women in Science and Engineering of the Office of Scientific and Engineering Personnel within the National Research Council, which advised the US federal government around policies for recruitment and retention of the scientific and engineering workforce, noted enormous potential for increasing the abysmal numbers of women in science and engineering careers. They offered a policy and strategy document to create a roadmap to do just that [13]. The report suggests improving science and engineering education by offering more funding for women, creating and maintaining female mentorship programs, documenting one-off success stories so they can be replicated, and addressing negative workplace climate issues for women around competition, harassment, uninspiring project assignments, lack of career mentorship, lower salaries, and poor family care policies. Furthermore, it emphasized the importance of evaluating the efficacy of existing programs aimed at reducing gender disparity in academia and the workforce, which included funding, mentorship, professional development and networking opportunities, and family care policies.

An NSF-funded conference focusing on barriers to and recommendations for improving the retention of women faculty members in two specific engineering disciplines, one of which was

Mechanical Engineering, occurred in 1993 [14]. The recommendations, which remain relevant today, include requiring gender workshops for all faculty, staff, and students; forming gender-issues committees to address and stop harassment; developing policies to improve fairness of teaching evaluations and tenure evaluation practices; creating support groups for women; allowing tenure clocks to stop and enabling family leave for people who have children; developing mentorship programs; and ensuring baseline safety around building access, lighting, and emergency phones. Trautner and colleagues also had specific entreaties for Department Chairs to treat people fairly and offer the same opportunities to all, and finally, they urged funders to be aware of and mitigate the impacts of prejudiced reviewers.

In 2001 the NSF ADVANCE program began funding critical research on barriers to achieving a diverse academic STEM workforce [11]. In line with informal discussions of these issues noted in the ASEE Prism article [12] and the NSF funded conference Trautner et al. discussed [14], this new body of research further illustrated the value of changing policies and procedures for faculty recruitment, promotion, and tenure, creating and maintaining programs to support better work-life balance, and developing and supporting mentoring programs. Notably, organizations that worked towards these changes noted better faculty job satisfaction and greater retention of women faculty members [11].

The NSF ADVANCE program then took the lessons learned from research further and began to specifically fund programs at organizations intending to *enact* these research-based strategies tackling the disparity in recruiting, retaining, and promoting women in STEM [11]. These strategies involve organizational changes to reduce the systemic barriers to women's success rather than focusing on addressing individual aspects of interest, skills, or self-confidence. One example of this is the University of Michigan in Ann Arbor's STRIDE (Strategies and Tactics for Recruiting to Improve Diversity and Excellence) model, developed initially with a 2001 NSF ADVANCE grant. This model created a faculty committee specifically tasked with raising awareness around the importance of recruiting women to tenure track faculty roles and offering support in many ways such as putting on workshops and developing hiring handbooks for search committees. Ultimately, the STRIDE program was institutionalized and given administrative support and embedded more consistently into the faculty recruitment process leading to increases in hiring of tenure track women engineering faculty (for a comprehensive look at the STRIDE program see [15]). Elements of this model have been copied widely in academia, government labs, professional societies, and the private sector [11].

Another program developed from an early NSF ADVANCE grant at North Dakota State University is the Advocates and Allies model which focuses on recruiting male STEM faculty who will be allies to female colleagues and work to dismantle barriers to their success. However, only when institutional resources are devoted to sustaining these programs, for example by housing them in faculty development offices, Diversity, Equity, and Inclusion offices, or Women in Science programs and making them priorities after external funding ends, do the programs tend to continue [11].

Despite all the progress made towards understanding how to address the representational disparity of women in STEM, by the mid 2010s percentages of women in STEM academia and the workforce remained stalled. In a comprehensive and impactful 2015 American Association of University Women (AAUW) report [1], President Obama is quoted in reference to this dismal lack of women in STEM, and in engineering particularly, “Half our team, we’re not even putting on the field. We’ve got to change those numbers.” The report continues to list some specific, though by now familiar, recommendations, which include increasing female role models, reducing harassment, communicating how engineering work supports societal common good, solidifying women’s sense of belonging, offering professional development and advancement along desired career paths, and creating policies that support non-work responsibilities. This AAUW report points to gender bias and gender stereotyping as underlying much of the educational and workforce gender disparity trends; and recognizes that this is a huge issue not easily and consistently solved. To that end, the report also specifically recommends that organizations eliminate gender from candidate application and evaluation forms, make managers at all levels accountable when they act in problematic ways, institutionalize gender diversity as an explicit organizational goal, and do outreach and place job postings where women and other underrepresented groups will see them. Building on the content in the AAUW report, Carpenter [16] offers a suite of concrete, well-tested actions that can mitigate unconscious bias that academic departments can take to successfully recruit more women faculty members in engineering or STEM broadly. These include several clear recommendations for the recruitment processes, for search committee work, and for interviewing practices.

An extensive 2023 review of psychology scholarship echoes the thread tracked and summarized in this literature review up to this point: person-level aspects like ability, interest, and “self-efficacy” (i.e. self-confidence in one’s ability to achieve a goal) do not fully explain the lack of women in STEM, and specifically engineering and that gender stereotyping especially in male-dominated spaces plays a significant role leading women to feel like they are not good fits, driving women out of the field [17]. The review offers yet more evidence that organizational changes like improving family leave policies, hiring diversity officers, and creating diversity task forces as well as offering mentoring programs can lead to long-term retention of women in STEM work environments. The importance of male allies was also highlighted, although specific strategies were not provided. These strategies aim to foster a sense of belonging and combat isolation in STEM organizations.

Fit is an incredibly important concept with respect to the gender dynamics in STEM, and a self-perceived lack of fit can absolutely drive women out of these career paths, and the engineering pipeline in particular. Seron and colleagues’ research [18] with undergraduate engineering students strongly suggests that unlike men, women often experience small though repeated gender stereotyping in their class project teams, internships, and summer jobs that over time make them question their fit in engineering. In line with other scholarship on this topic, the authors suggest that both the engineering curriculum may need to change, and workplace climate and culture will need to change as well. Relatedly, a recent preprint from the Economics literature offers direct evidence through transcript analysis and survey data that women, particularly first year students, choose not to take courses in and major in the STEM, business, and economics fields specifically because of anticipated discrimination in the workforce in those fields [19]. Indeed, they find that greater anticipated discrimination in the workforce in these fields correlated with a 9% reduction in women choosing to major in STEM, business, and economics.

The emphasis on systemic and cultural change is crucial, as even with progress, unforeseen events can exacerbate existing inequalities. The COVID-19 pandemic serves as a stark reminder of this, revealing vulnerabilities in the support systems for women in STEM. Research suggests that the workforce effects of the COVID-19 pandemic will include encouraging growth in STEM fields broadly over the next five years [20]. However, looking back at the pandemic's effects on the rates women left the overall workforce shows that women left more than men. Moreover, women with children, especially younger children, left at greater rates than men, and women earning lower wages and women of color were disproportionately leaving the workforce more relative to white women [21], [22]. So, while STEM occupations may indeed grow in the near future, the gender gap in the engineering workforce likely will remain.

Over the past several decades, evidence has surfaced repeatedly that women's interests and abilities in engineering cannot be the entire reason they leave academia and the workforce. Policies, practices, stereotyping, sexism, harassment, anticipated discrimination, and overall culture and climate can lead women to stall in their career path, leave the field, or never fully enter it (for an even more detailed thematic analysis of the literature around women faculty in engineering that remains quite relevant to women in the engineering workforce, see Blackburn [8]). Figure 2 offers a concept map illustrating these key factors impacting gender diversity in engineering. Research, summarized in Figure 3, has also unearthed several strategies and solutions that seem to work when put to use to retain and promote women in engineering. Now, in the 2020s, one might wonder: has any of this yet made a dent? We look at trends in the percentages of women represented in engineering academia and the engineering workforce to begin to answer that question. This review categorizes the literature into three main themes: 1) organizational factors, 2) individual factors, and 3) intervention strategies, to systematically examine the issue and its proposed solutions.

Fig 2. Concept map derived from the literature of drivers of gender inequality in engineering.

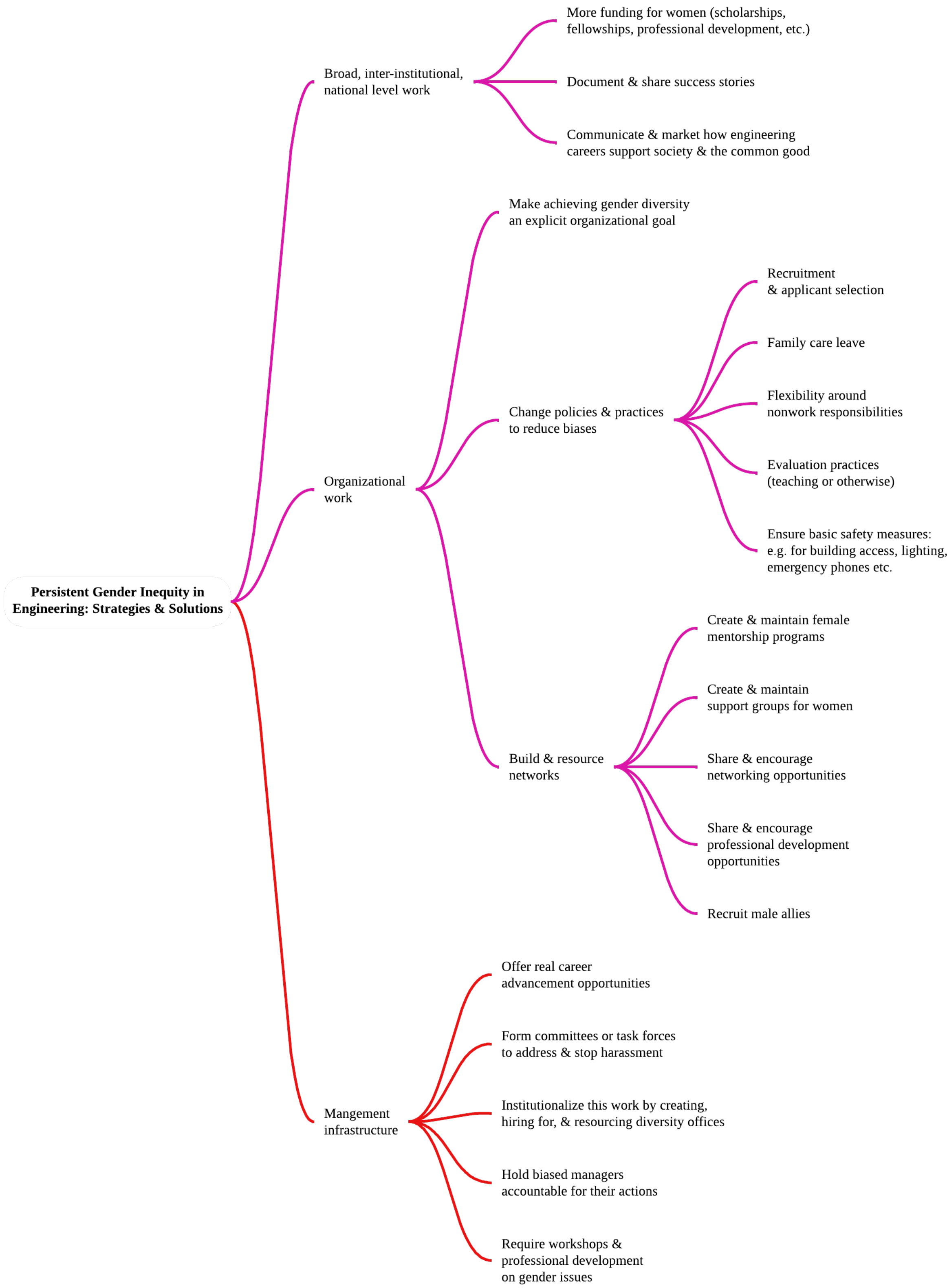

Fig 3. Concept map derived from the literature of strategies and solutions of gender inequality in engineering.

Data Collection and Results

Data on the percentages of women at all levels of engineering academia were retrieved from the ASEE data center and are voluntarily reported by institutions across the United States to ASEE. It is important to acknowledge the limitation that the ASEE data relies on voluntary reporting from institutions, which might introduce some biases. However, it is the most comprehensive data set available. Data from the University of Michigan on the percentages of women at all levels of engineering were retrieved from the University's Registrar's office and requested from the College of Engineering. Data concerning the percentages of women working in the engineering workforce and the mechanical engineering workforce in the U.S. were retrieved from the Bureau of Labor Statistics survey "Labor Force Statistics from the Current Population Survey" [23], [24]**.** To make comparisons easier, all figures utilize the same Y axis scales, when displaying percentage data.

Figure 4 depicts the trends from 2005 through 2023 in the percentages that women make up of the Mechanical Engineering (ME) academic landscape across the U.S. according to the ASEE data available. Trends show steady but very small increases across this time period in the percentages of women represented at all levels of academia: undergraduate, Masters, and PhD students as well as tenured and tenure track faculty members. Women make up the highest percentages in the PhD student populations, steadily increasing to a maximum value of 22% in 2023. But in other groups, women remain at levels under 20%. Despite the observed growth, the percentages remain very low, underscoring the persistent gender disparity.

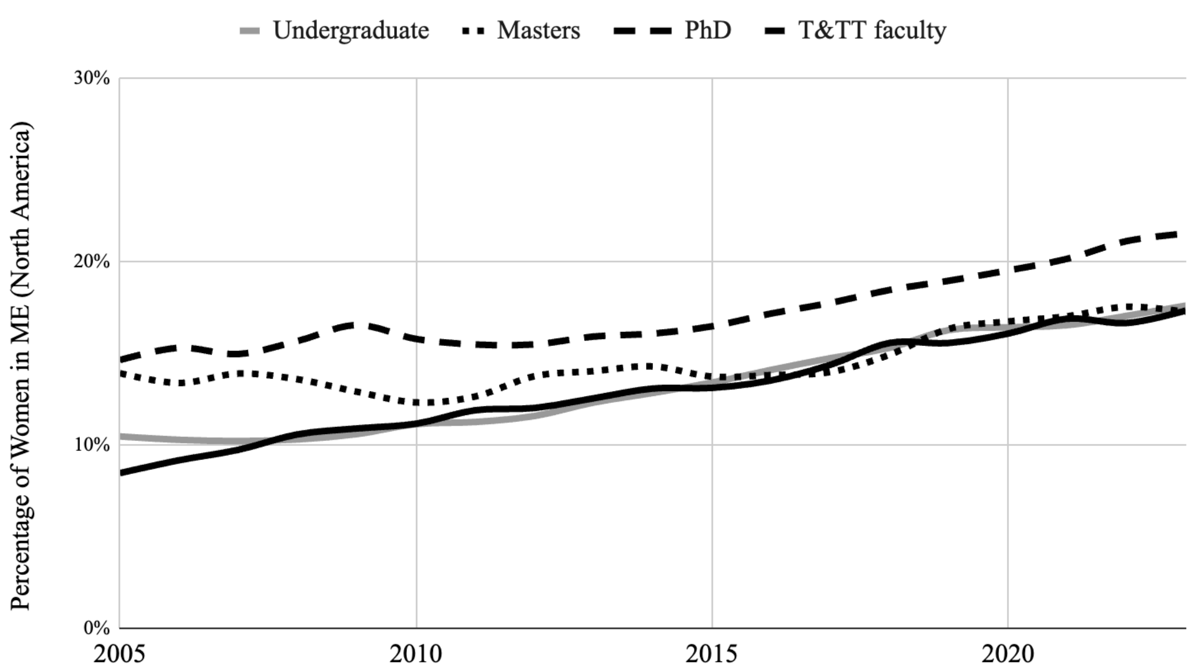

Fig. 4. Trends of the percentages of women represented in ME undergraduate, Masters, and PhD programs across the U.S. and in the percentages of women making up ME tenured and tenure track faculty populations in engineering departments across the U.S.

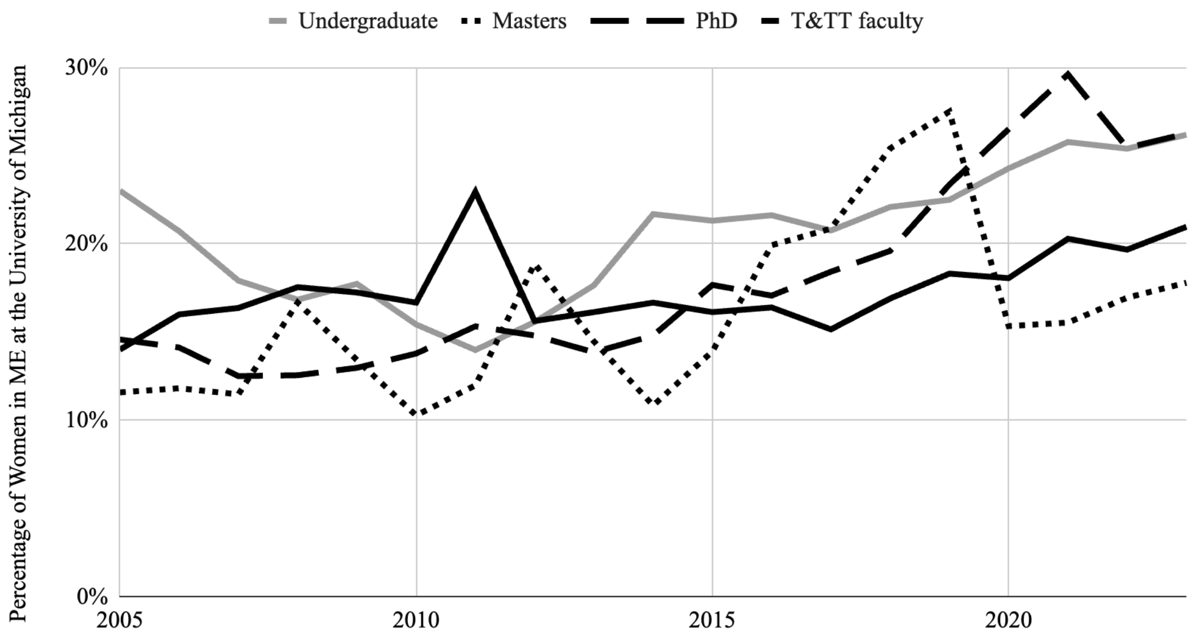

Fig. 5. Trends of the percentages of women represented in ME undergraduate, Masters, and PhD programs in the University of Michigan ME department and in the percentages of women making up tenured and tenure track faculty populations in the University of Michigan ME department.

Figure 5 displays the trends from 2005 through 2023 in the percentages that women make up of the Mechanical Engineering (ME) department at the University of Michigan. Trends show more variability in the percentages of women represented in each population over time, which is expected due to the smaller sample size (the number of ME faculty members ranges from 50-70 in this department). No one population has consistently greater ratios of women than others. Overall, the University of Michigan's ME department has trended towards having slightly higher percentages of women undergraduate students than the US average. This is also true for PhD students and tenured and tenure track faculty members in more recent years. The Masters student population is highly variable and is not consistently higher or lower than the US average.

Figure 6 draws on ASEE and the University of Michigan data to compare the percentages of women undergraduates in any engineering department in the U.S. dataset, any ME major in the U.S. dataset, any engineering major at the University of Michigan, and in the ME department at the University of Michigan. ME departments, both in the U.S. dataset and within the University of Michigan data, have fewer percentages of women undergraduates relative to all engineering majors. The University of Michigan consistently had higher percentages of undergraduate women students in all engineering departments and in the ME department in particular relative to the U.S. averages.

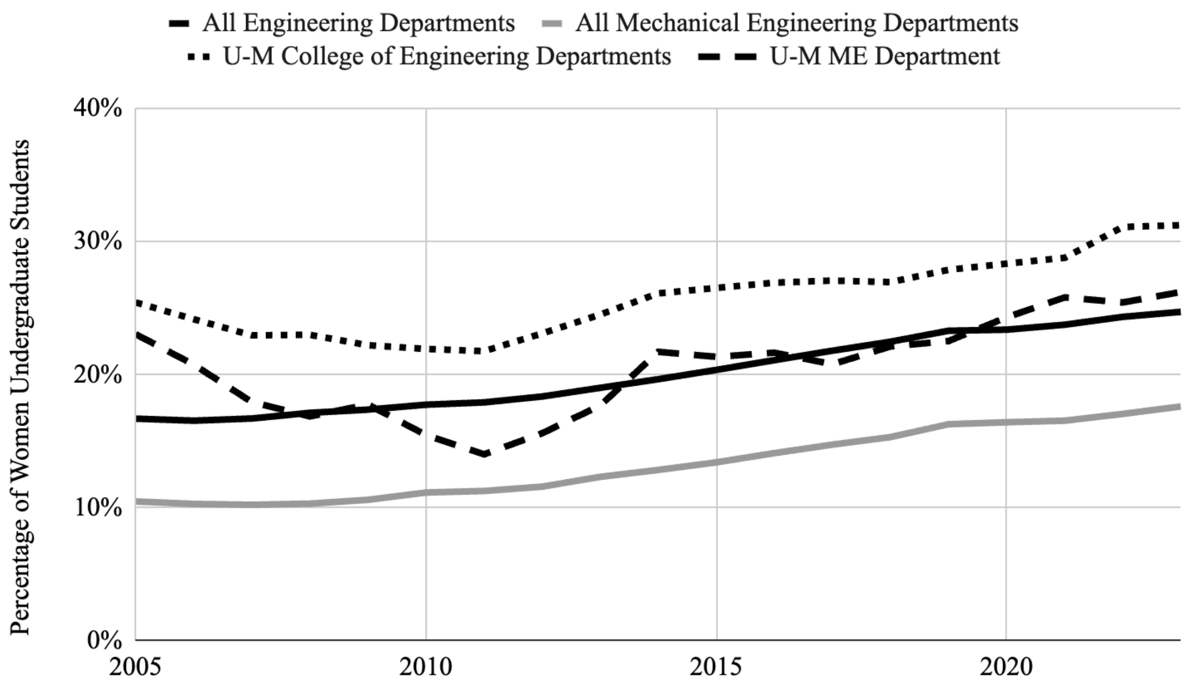

Fig. 6. Percentages of women undergraduate students in any engineering department in the U.S. dataset, any ME major in the U.S. dataset, any engineering major at the University of Michigan, and in the ME department at the University of Michigan.

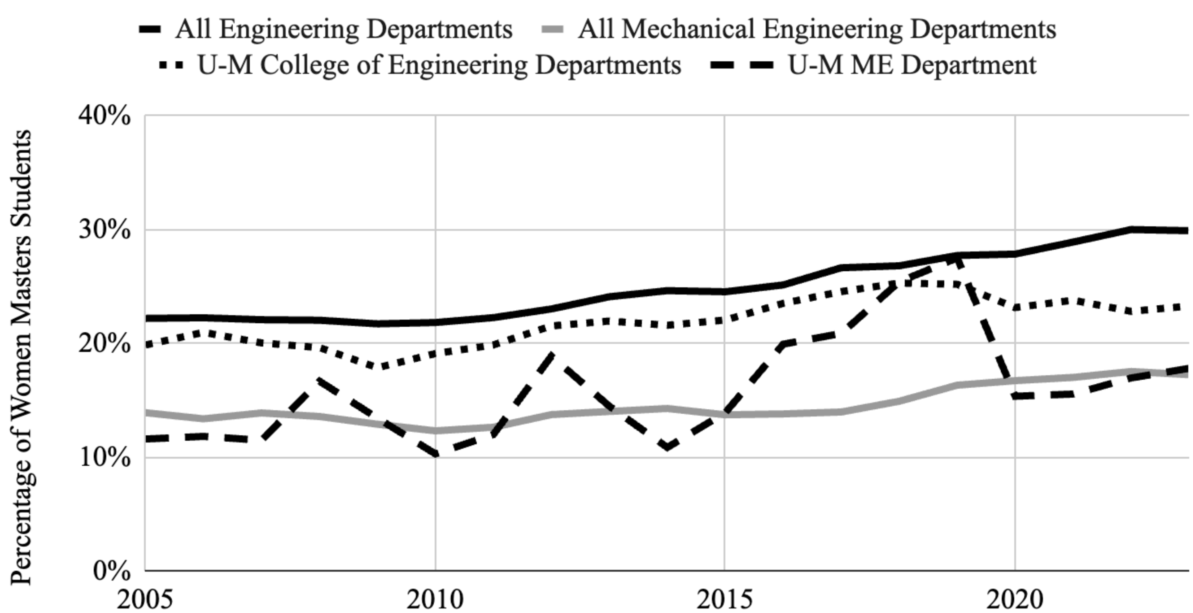

Fig. 7. Percentages of women Masters students in any engineering department in the U.S. dataset, any ME major in the U.S. dataset, any engineering major at the University of Michigan, and in the ME department at the University of Michigan.

Similarly, Figure 7 presents a comparison of the percentages of women Masters students in any engineering departments in the U.S. dataset, any ME majors in the U.S. dataset, any engineering majors at the University of Michigan, and the ME department at the University of Michigan, using ASEE and the University of Michigan data. The percentage of women engineering Masters students in the College of Engineering at the University of Michigan is consistently lower than that of the overall U.S. average for women engineering Masters students. Again, there is huge variability in the percentage that women make up of the University of Michigan ME department, oscillating between being on par with and generally higher than the percentage of women engineering Masters students in ME departments across the U.S. Whether comparing within the University of Michigan or within the national averages, ME has lower rates of women masters students than the whole field of engineering has.

Figure 8 again employs ASEE and University of Michigan data to compare the percentages of women PhD students in any engineering department in the U.S. dataset, any ME major in the U.S. dataset, any engineering major at the University of Michigan, and in the ME department at the University of Michigan. The percentages of women engineering PhD students in all engineering departments at the University of Michigan consistently tracks with the US average. The same relationship was true for PhD students in the University of Michigan ME department relative to the U.S. average until the last five years when the percentages increased at the University of Michigan relative to the U.S. average. Overall, the PhD student population demonstrates steady, if still slow, growth in the percentages of women represented across all populations.

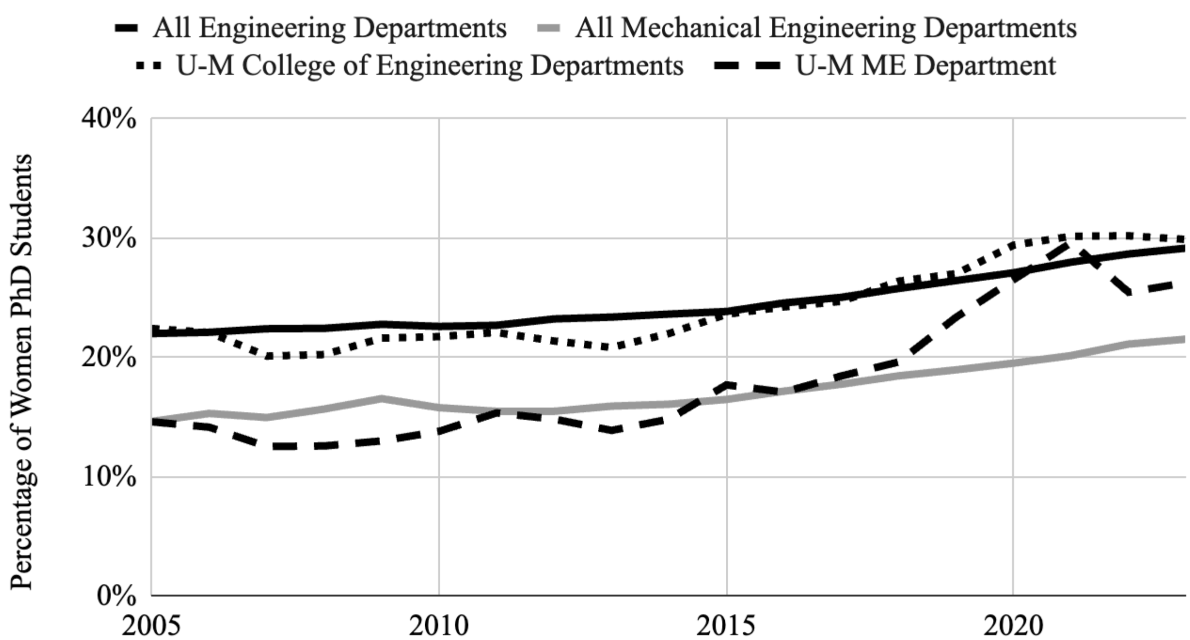

Fig. 8. Percentages of women PhD students in any engineering department in the U.S, dataset, any ME major in the U.S. dataset, any engineering major at the University of Michigan, and in the ME department at the University of Michigan.

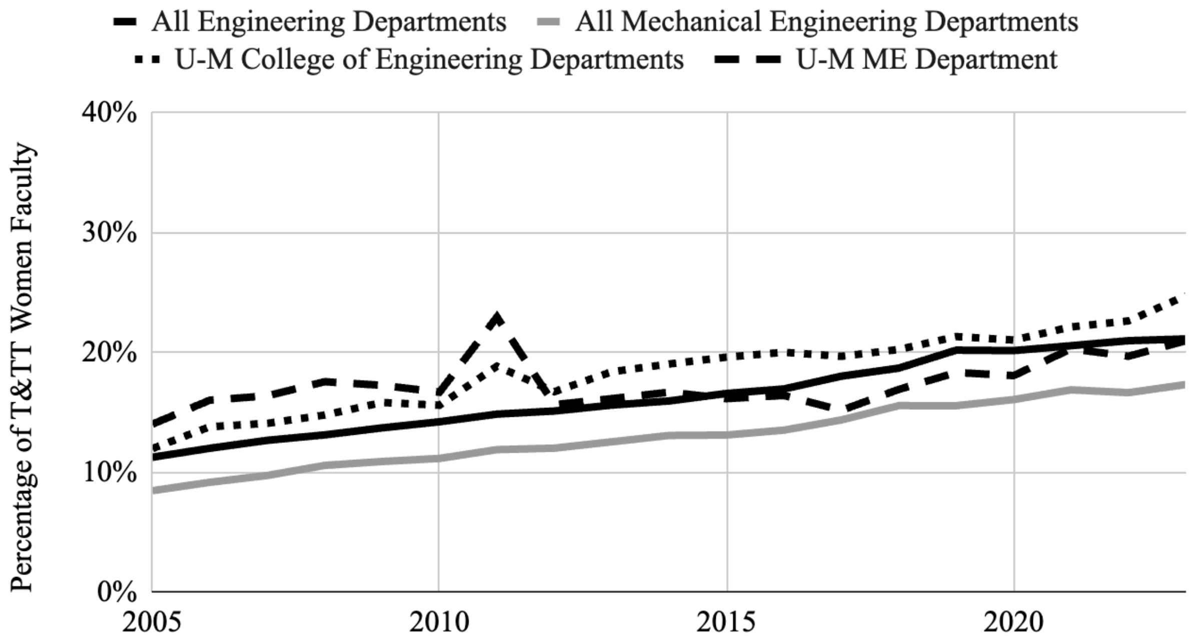

Fig. 9. Percentages of tenured or tenure track women faculty members in any engineering department in the U.S. dataset, any ME major in the U.S. dataset, any engineering major at the University of Michigan, and in the ME department at the University of Michigan.

Figure 9 uses ASEE and the University of Michigan data to compare the percentages of women who are tenured or in tenure track faculty positions in any engineering department in the U.S. dataset, any ME major in the U.S. dataset, any engineering major at the University of Michigan, and in the ME department at the University of Michigan. There is consistent, but slow, increases in the percentages of women in engineering faculty roles across all population groups. Still, especially in the last ten years, the percentage of women in ME is lower than the percentage of women in all engineering departments both for the U.S. average and for the University of Michigan. The University of Michigan does have small but consistently higher percentages of women faculty in ME and engineering generally relative to the U.S. averages for those populations.

Figure 10 uses U.S. Bureau of Labor Statistics data to compare the percentages of women in the engineering workforce generally with those in the ME workforce. ME has consistently lower percentages of women relative to the overall engineering workforce. Growth in both categories is inconsistent and slow.

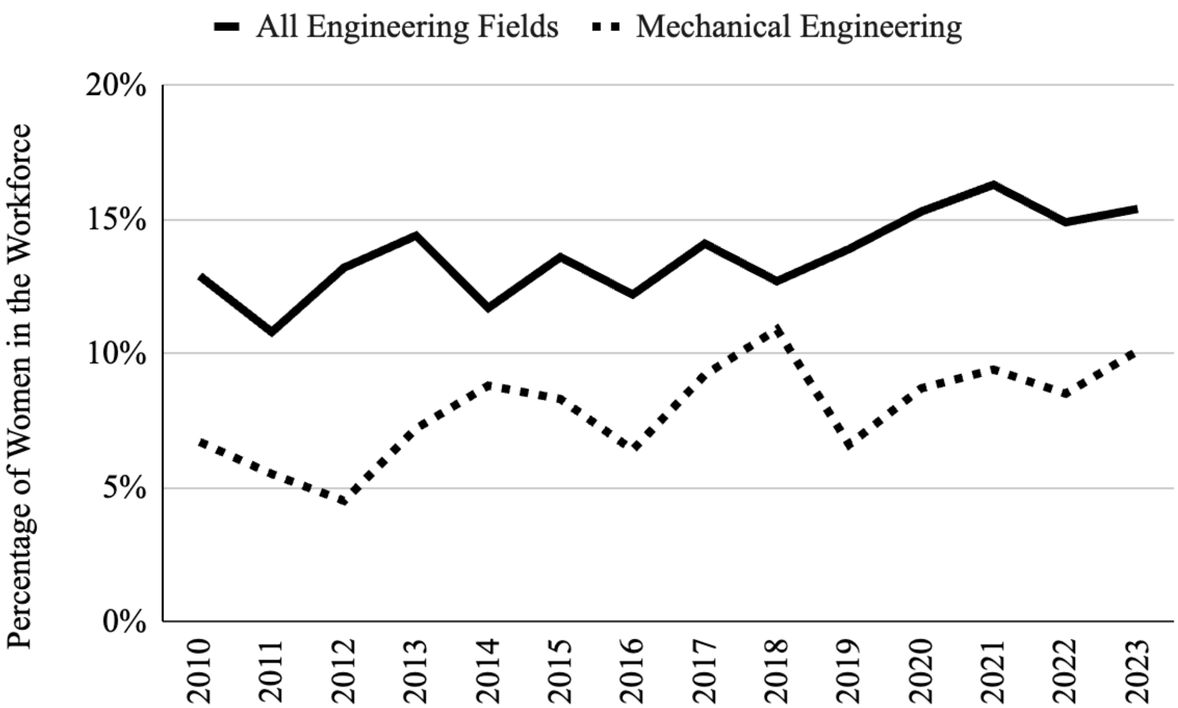

Fig. 10. Percentages of women in the U.S. engineering and mechanical engineering workforce.

Discussion

Overall, each figure shows that the percentage of women represented across various levels of engineering is low. Furthermore, across all populations, ME as a discipline consistently exhibits a lower percentage of women relative to all engineering fields combined. While the University of Michigan has instances where women make up 30% of the engineering population, the underrepresentation of women in engineering, and in ME specifically, is clearly a reality at this institution. Here, our data mirror the national trend: a persistent relative lack of women in ME classrooms and faculty offices.

Historically, ME's association with heavy industrial processes and machinery may have fostered a perception of incompatibility greater than for other disciplines for women and their professional interests and identities, further reinforced by a scarcity of visible female role models. However, because the field of ME is itself large relative to other engineering sectors, if ME could reach gender parity, it would vastly increase the numbers of women in engineering generally. Data from ASEE, though, do offer some glimmers of hope to this pipeline issue as the percentage of women ME PhD students is consistently higher than other population groups, and consistently (though, again, slowly) growing. Those with PhDs are well-positioned to stay in academia or enter the workforce, and so continuing increasing gender parity in the PhD population is helpful to the picture of the field of engineering overall.

The effect of the COVID-19 pandemic is not immediately clear in these data. However, the only population that showed a drop around the time of the pandemic was the ME Masters students at the University of Michigan where the percentage of women dropped from 28% in 2019 to 15%

in 2020 with only miniscule gains since that date. However, enrollment in this group also dipped in 2010 and 2014, so conclusions about the reasons behind this drop are unclear. Interestingly, the percentage of all engineering Masters students at the University of Michigan did not suffer, so the drop in ME Masters students was offset by gains in other departments.

Still, the full range of the pandemic's effects on gender parity in engineering may not be fully realized for years. Anecdotally, the University of Michigan, in collaboration with the Women in Science and Engineering office at this institution, used to host middle school girls for a special sleepover event to learn about engineering; these have ceased and there is no sign they will return. Also, while some women may have chosen to leave engineering academia and the engineering workforce all together when the pandemic hit, it may be that some institutions and organizations updated family-related policies as remote work and other practices have become the norm.

Source after source, across the decades, note that a lack of women in STEM generally, and often specifically in engineering, is not explained solely by any differences in individual interests and abilities. This body of literature strongly concludes that changing organizational culture, policies, and practices, though often extremely difficult, is crucial to improving their numbers in both academia and the engineering workforce ([1], [7], [14], [17], [25]). The path towards gender parity may face increased challenges in the coming years due to shifts in national-level policies and funding priorities. This trend underscores the importance of institutional commitment and sustained resource allocation to maintain and advance gender equity [26].

However, to achieve success and equalize the percentages of women in engineering, it remains critical to prioritize this work in organizational missions and strategic goals, to devote and sustain funding for this work, and to institutionalize this work in the form of organizational practices, workflows, and structures [11]. As Jeff Meade wrote in "The Missing Piece" in the September 1991 inaugural issue of the ASEE Prism, "While women don't necessarily need engineering, engineering clearly needs them" [12].

Next Steps for This Work

This work establishes a foundation for understanding the persistent underrepresentation of women in ME. The data presented here underscore the ongoing need to address this disparity across all academic levels and within the workforce. Building on this foundation, several key avenues for future work emerge.

Continued research along the lines of those discussed in the literature review remains critical, including exploring the lived experiences of women in ME. For example, are there aspects of the ME curriculum that perpetuate gender stereotypes or create a less inclusive learning environment? Are there specific cultural norms within ME departments that discourage women from pursuing or remaining in the field? While this paper focuses on quantitative data, future research should delve into the nuances of women's experiences through in-depth interviews and focus groups, and similar methods.

This qualitative approach aligns with our ongoing book project at the University of Michigan, which aims to share the stories of women in our ME department, highlighting their achievements and the challenges they have faced. This book will contribute to a broader understanding of the challenges and opportunities for women in ME academia, exploring what ME scholarship might have lost without their contributions, and ultimately, hopefully, inspiring future generations of women ME scholars. Specifically, the qualitative research will seek to identify the cultural and curricular factors that contribute to women's experiences in ME, and how these factors impact their sense of belonging and career trajectories.

To advance women's representation in ME, rigorous evaluation of interventions is crucial. Future research should continue to examine the effectiveness of mentorship programs, family-friendly policies, and other initiatives to illuminate when, how, and in what contexts these strategies succeed or fail. Comparative institutional analysis, examining the experiences of women in ME across different institutions, could reveal best practices and identify institutional factors that contribute to greater gender equity in these institutions. Finally, longitudinal studies could provide insights into women's career trajectories in ME, tracking their progress from undergraduate studies through their professional lives to identify critical points of attrition.

Ultimately achieving equitable participation in ME, engineering, and STEM broadly requires sustained institutional commitment, dedicated resources, and the implementation of evidence-based practices. Translating research findings into actionable recommendations for institutions and advocating for effective policies are essential steps toward creating lasting change.

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