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Breaking Barriers for Women in STEM: Uncovering Career Challenges and Transformative Educational Strategies: A Case Study in Architecture and Related Engineering Fields

Dr. Tianjiao Zhao, East Carolina University

Tianjiao Zhao joined the Department of Construction Management at East Carolina University as an assistant professor in Fall 2022. With a robust background in semantic web technologies, intelligent transportation, BIM, green building, Lean Six Sigma, Internet of Things, and water engineering, she brings extensive expertise to her role. Maintaining an active research agenda, her work primarily revolves around enhancing the efficiency, safety, and eco-friendliness of the construction industry. Additionally, she is dedicated to integrating cutting-edge technologies into her teaching methods to elevate the overall educational experience.

Dr. Xi Lin, East Carolina University

Dr. Xi Lin is an associate professor at East Carolina University, US. Her research focuses on seeking best practices to enhance student engagement and interaction in online learning environments. More information can be found at http://whoisxilin.weebly.com/

Dr. Xi Wang P.E., Drexel University

Xi Wang is an Assistant Professor of Civil Engineering at the University of Mount Union. She received her Ph.D. and M.Eng both in Civil Engineering from the University of Kentucky and Auburn University. Her research interests include the application of Unmanned Aerial Vehicle in construction management, Lean Construction, and liberal arts in engineering education.

Yidan Zhu, Texas State University
Pianpian Huang, East Carolina University
Bingbing Li, University of British Columbia, Vancouver
Qiuhan Ji, University of British Columbia, Vancouver

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Abstract

The Science, Technology, Engineering, and Math (STEM) industry has experienced significant growth over the past few decades, yet the representation of women in these fields remains disproportionately low. This study explores transformative educational strategies through interviews and surveys with 35 women currently or previously employed in architecture, construction, and adjacent STEM industries. Key areas examined include educational backgrounds, career pathways, professional development, interpersonal dynamics, and valued workplace characteristics.

Findings highlight that women in STEM fields continue to face significant challenges, including gender bias, social isolation, limited career advancement opportunities, insufficient mentoring, and difficulties balancing work and life responsibilities. Despite progress in K-12 STEM education, 65% of participants first considered STEM careers during higher education, often after age 19. Most learned about STEM careers primarily through online resources such as virtual courses, highlighting digital platforms as key for attracting and supporting women's career development, while college career services, despite their pivotal role in career preparation, had minimal impact on their career readiness. Notably, 70% of women reported either personally experiencing or witnessing gender bias and related challenges, which not only affect their current work performance but also influence their sustained long-term engagement in STEM fields. Caregiving responsibilities further restrict women's career choices and long-term professional growth. Encouragingly, women have demonstrated a strong awareness of emerging technologies, with each individual, on average, having explored over six new technologies.

This study combines survey data and in-depth interviews to capture the experiences and narratives of women in STEM, providing insights into the systemic factors contributing to their underrepresentation along with the emerging and changing trends in the field. It offers evidence-based recommendations for educators and educational institutions, emphasizing the necessity of targeted interventions such as K-12 STEM career education, mentorship programs, enhanced college career services, harassment awareness and support, inclusive learning environments, and policy reforms to promote gender equity. By informing academic discussions on STEM diversity, this study guides future research and institutional strategies aimed at attracting more women to STEM fields, improving their career entry and advancement, and fostering a more inclusive professional pipeline.

Keywords: STEM Women, Gender Equity, Gender Bias, Career Dilemmas, Inclusive STEM Education Strategies, Mentorship and Policy Reform

Introduction

The Science, Technology, Engineering, and Mathematics (STEM) industry has experienced significant growth over the past few decades, driven by economic development, technological advancements, and the increasing demand for innovation [1]. Despite this expansion, gender disparities persist, with women remaining significantly underrepresented across STEM fields [2]. Particularly some STEM fields, such as construction-related engineering disciplines—have traditionally required substantial physical effort. Inclusive technologies, such as remote-controlled tools and automation, may help to lower barriers to entry. However, systemic challenges continue to hinder women's participation and long-term success in STEM careers. Specifically, women in STEM often face barriers such as limited mentorship, gender bias, restricted career advancement opportunities, ineffective college career services, and caregiving responsibilities (e.g.,[3], [4], [5]), all of which impact both early career development and long-term retention.

Therefore, this study explores the experiences of women in STEM industries, providing evidence-based recommendations and development strategies by examining the roles higher education institutions and policymakers can play in supporting women. The research questions are categorized into the following key areas:

- Work experience
- Career entry timing and pathways
- Gender bias and workplace challenges
- Familiarity with emerging technologies
- Core values and workplace concerns
- Recommendations for attracting and retaining women in STEM

By exploring both educational and professional experiences, the study highlights the significance of mentorship, institutional support, and policy-driven strategies in improving gender equity. Its unique contribution lies in its focus on the intersection of educational pathways with professional experiences, emphasizing the need for targeted interventions such as inclusive learning environments, mentorship programs, and institutional reforms to promote retention and career advancement for women in STEM fields.

While this study broadly addresses challenges faced by women in STEM, the research specifically focuses on participants from architecture, civil engineering, and related industries, reflecting the recruitment strategy and practical constraints of the study.

Literature review

Underrepresentation of women in STEM

Young children absorb social role messages and self-perceptions through both direct teaching and subtle influences. Unconsciously, parents may expose young girls less to math and science, leading to gaps in understanding compared to boys [6]. Such stereotypes that girls are less interested than boys in computer science and engineering emerge early and may contribute to gender disparities [7]. As a result, women's high attrition in STEM majors is usually driven by a lack of support, hostile environments, and limited research access [8]. Such stereotypes furthermore lead to the underrepresentation of women in STEM fields, which has been a persistent issue, with implications for innovation, economic growth, and social equity. Despite efforts to bridge the gender gap, women continue to face numerous challenges that hinder their participation and advancement in STEM, particularly in the industrial sector.

Studies reveal significant gender disparities in STEM, with women underrepresented at all stages of participation, from primary education to early career phases [9]. J. Childers et al. [10] conducted longitudinal studies on women's progression in STEM, showing some improvement in degree attainment, yet structural barriers and gender gaps persist. Dawson [8] explored career persistence among women students, finding that attrition rates remain high as female students transition from academia to the workforce. Therefore, this ongoing underrepresentation is not simply due to a lack of personal interest or ability but stems from complex factors, including societal norms, educational experiences, and workplace environments.

Approaches to address the issue

Multiple strategies have been proposed to address women's underrepresentation in STEM. For example, educational interventions, such as gender-balanced teaching and inclusive curricula, should be encouraged to boost women's participation and confidence in STEM [11]. Additionally, hands-on training, lab courses, and collaboration could be provided, which would enhance their career readiness and related skill acquisition [12]. Schools should also offer mentorship, career workshops, and equity policies to increase female participation and support their success in STEM employment, career advancement, and leadership roles [13]. Studies showed that outreach initiatives targeting girls at an early age, scholarships and financial aid, and mentorship programs connecting women with role models and peers have proven effective as well [14]. Finally, inclusive learning environments and financial support, such as scholarships, should be encouraged, contributing to women’s participation and job alignment in STEM [15].

Meanwhile, it is necessary for governments to combat STEM gender discrimination through investing in early education, enforcing stronger policies, promoting workplace diversity, and improving discrimination metrics [16]. Gender-inclusive policies, such as flexible work and parental support, should be promoted to help retain women in STEM by easing family-care conflicts. Fostering inclusive workplaces through bias training, flexible policies, and mentorship would additionally enhance diversity and retention [17]. Moreover, environments that foster belonging have proved to be an effective way to successfully recruit, retain, and advance girls and women in STEM [9]. In other words, women who engage in female-majority groups usually have high confidence and career aspirations, compared to those in female-minority groups. Thereby, forming female-majority groups is significant to boost women's participation and retention in engineering [18].

Challenges and barriers for women in STEM

However, today, women in STEM still face numerous challenges, with implicit and explicit gender bias hindering career advancement and job satisfaction. Specifically, Wang and Degol’s study [19] concluded that women in STEM often face challenges including lower self-perceived employability compared to their male counterparts, reduced leadership opportunities, and persistent societal stereotypes discouraging their participation in technical fields. These biases appear subtly and overtly throughout professional trajectories, from hiring processes—where unconscious bias can favor male candidates—to performance evaluations that undervalue women's achievements or attribute them to factors other than competence [20].

Moreover, tokenism in male-dominated fields heightens scrutiny and isolation for women, compounded by limited support and mentorship, restricting their career growth [21]. Work-life balance is another critical challenge. Particularly, the demanding nature of STEM jobs, often characterized by long hours and high-pressure environments, frequently conflicts with societal expectations around women's caregiving roles. This tension forces many women to choose between professional ambitions and personal responsibilities, leading some to leave the workforce or reduce their career goals [22]. Furthermore, unequal pay with women in STEM being paid approximately 14% lower than their male counterparts, can reduce women's loyalty and ability to stay in STEM jobs, making it a key factor in retention [23]. Accordingly, Johnson and colleagues [24] noted that discrimination and male domination in the academic science, engineering, and medicine climate create a permissive environment for sexual harassment, limiting career opportunities for both victims and bystanders and resulting in talent loss, which institutions can mitigate through systemic changes that demonstrate a commitment to addressing the issue and listening to those who speak up.

Theoretical framework

To explore the career challenges of women in STEM, particularly in male-dominated fields like architecture and construction, this study applies Gender Equity Theory [25], Intersectionality Theory [26], Social Cognitive Career Theory [27], and Expectancy-Value Theory [28]. These frameworks collectively provide a multidimensional perspective on the structural barriers, compounded biases, psychological factors, and career expectations that shape women's experiences in STEM.

Gender Equity Theory highlights systemic disparities by examining the unequal distribution of resources, opportunities, and rewards, emphasizing the need for institutional and societal reforms to foster equity in education and the workplace. Intersectionality Theory extends this analysis by recognizing how gender intersects with race, ethnicity, and socioeconomic status, amplifying challenges for women of color in STEM who face both racial and gender bias, which can hinder career advancement and impact mental well-being.

To further explore individual career trajectories, Social Cognitive Career Theory is incorporated to examine how self-efficacy, positive outcome expectations, and external support influence women's retention in STEM, while also acknowledging the role of barriers, such as unsupportive environments, in limiting long-term persistence. Lastly, the Expectancy-Value Theory was used to analyze how the sociocultural, biological, and psychological factors influencing STEM women’s career choices, thereby exploring how field-specific characteristics contribute to their unique challenges. By integrating these theories, this study provides a comprehensive framework to understand both systemic and individual factors affecting women’s STEM career pathways.

Methodology

Research design

This study used a mixed-methods approach, combining quantitative data from surveys and qualitative insights from interviews to explore the work dilemma faced by women in STEM fields. The mixed-methods design was chosen to capture both numerical trends and in-depth personal experiences, providing a holistic understanding of the challenges and perceptions among women in STEM professions. This study was approved by the Institutional Review Board (IRB) of the authors’ university.

Sample population
The research involved 35 women working or having recently worked in STEM industries across the United States, including North Carolina, California, Texas, and over ten other states. While this study initially sought participants from a broad range of STEM fields, the final sample primarily comprised respondents from construction firms, engineering and technology colleges, and professional organizations supporting women in engineering. The participants represented diverse professional roles, education levels, and experience ranges. Participants from employees of large architecture-related companies and members of women's professional development organizations to ensure familiarity with current industry developments and representativeness.

Data collection and instruments
Data collection included an online anonymous survey and a following one-on-one semi-structured interviews conducted either online or in person. The survey, hosted on the Qualtrics platform, comprised 20 questions designed after an extensive literature review and consultations with multiple female professionals with over a decade of STEM experience. The questions aimed to capture participants' career trajectories, STEM entry points, perceptions of gender bias, familiarity with emerging technologies, and core professional challenges. The survey was estimated to take approximately 20 minutes to complete. Sample questions include: *How did you learn about STEM careers?* And *By what means did you get your job?*

The semi-structured interviews lasted approximately 30 minutes and were conducted via online meetings, phone calls, or face-to-face meetings to ensure that the participants felt comfortable while sharing their experiences. Interviews began with a brief introduction to the study's purpose, followed by open-ended questions designed to capture participants' insights. To maintain confidentiality, no recordings were made, and responses were documented solely through researcher notes. Participants were informed of their right to withdraw at any time, and all data was handled securely, with only nicknames and contact emails retained for follow-up. The sample interview questions include: *Can you recall a specific moment in your academic or professional journey when you clearly experienced a gender-related challenge or bias? What was the situation, and how did you handle it?* And *In your education or training, were there particular teaching methods or learning experiences that you found especially supportive or, conversely, lacking? What skills or knowledge do you think should be emphasized more to help women navigate professional challenges?*

Participants and data analysis
A total of 99 participants registered for the study, with 35 completing the survey, among whom 27 also participated in follow-up interviews. The sample size was deemed sufficient for qualitative richness and theoretical saturation. While the modest sample size limits broader generalizability, the study's depth and the diversity of experiences captured provide significant insights into the gendered dynamics of STEM professions.

Quantitative survey data was examined through descriptive analysis to identify patterns and trends related to career entry points, exposure to new technologies, and gender bias perceptions. Meanwhile, qualitative interview data provided deeper narratives and context on women's experiences with gender bias and their coping strategies.

Results

Due to space constraints, detailed findings from the analysis of 20 questions are summarized into the following six sections.

Work experience and representativeness

As shown in Figure 1, only 12% of participants had less than one year of work experience in STEM fields, with most having considerable professional experience, ensuring representativeness. Insights from the interviews revealed that the most common roles among participants were Estimator (30%), Educator (21%), Architect (15%), Project Manager (12%), and Civil Engineer (9%).

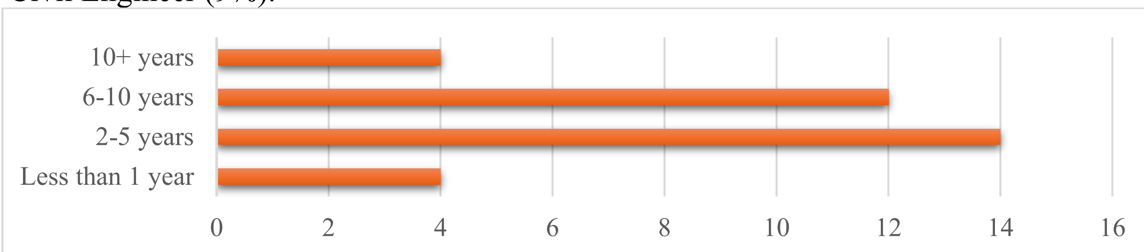

Figure 1. Distribution of Participants' Work Experience in STEM Fields.

Career entry timing and pathways

Despite the promotion of STEM-related courses in K-12 education, participants reported that their formal consideration of STEM careers often began after high school or even after college graduation, with 65% starting after age 19 (see Figure 2). This timing appears significantly delayed compared to their male peers, who often begin exploring STEM fields through internships either before or during their early college years [29].

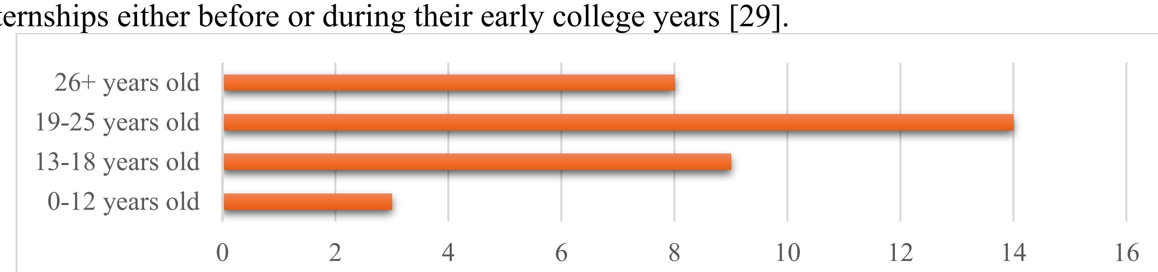

Figure 2. Timing of Formal Consideration for STEM Careers.

The most common ways participants learned about STEM careers were through online resources, such as online courses (47%), YouTube channels (35%), blogs (24%), and magazines (26%), and professional association (38%) (see Figure 3). This finding highlights the substantial potential of online education, virtual learning platforms, and remote mentoring in introducing, attracting, guiding, and preparing women for early STEM career readiness.

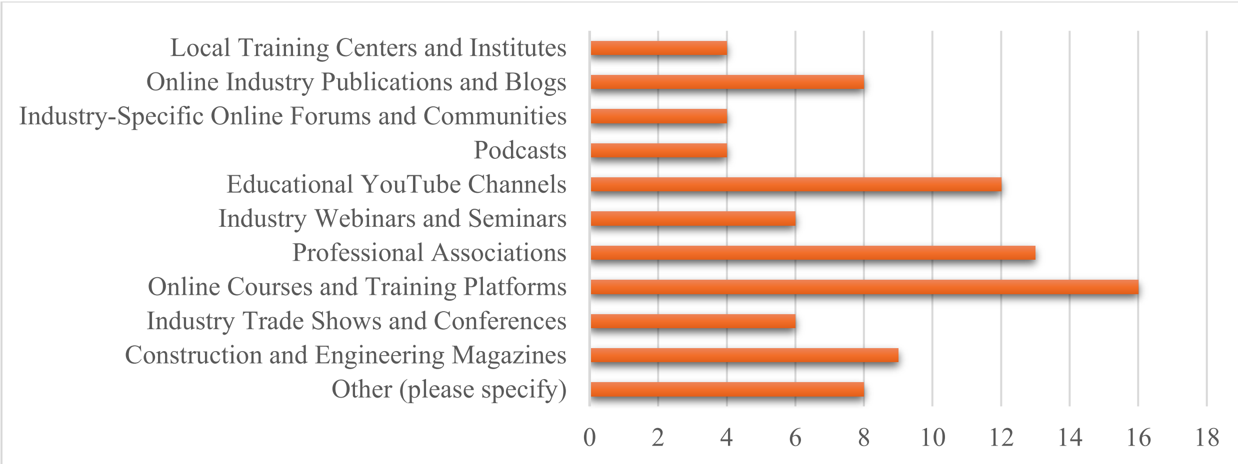

Figure 3. Pathways to Learn About STEM Careers.

Participants entered STEM primarily through online job boards (26%) and company websites (12%), closely followed by personal referrals (24%). Disappointingly, college career services—despite their expected role as a critical support system for female students entering the job market—played a minimal role, contributing only 3% (Figure 4).

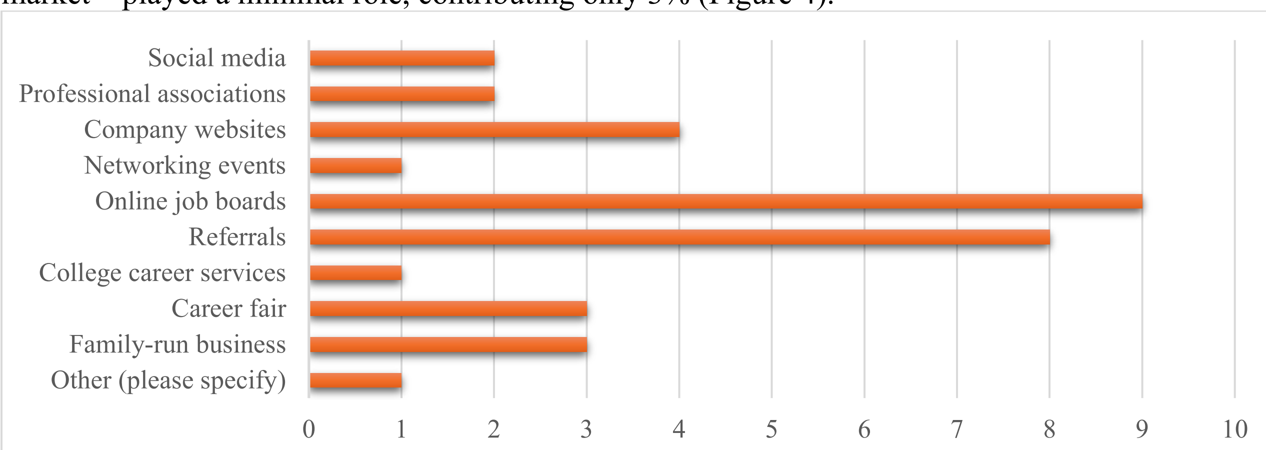

Figure 4. Pathways into STEM Fields.

Gender bias and workplace challenges
The majority (74%) of the interview participants confirmed the importance of diversity in STEM fields (see Figure 5). Alarmingly, 70% of the women interviewed reported either personal experiences or witnessed instances of gender bias and workplace challenges. These included being questioned about their competence, receiving lower salaries than male colleagues, experiencing harassment, facing a lack of women-friendly facilities, emotional isolation, and limited inclusion within teams (see Figure 6). Based on the interview results, the severity of the incidents and the resulting psychological stress clearly exceeded mild levels, with some participants even encountering multiple instances of bias, further exacerbating significant emotional strain. This intensity was not initially anticipated during the survey design, so the questions were limited to yes/no responses without follow-ups on severity. Fortunately, the interviews helped capture this critical detail, revealing a concerning reality that underscores the need for more deep investigation of workplace challenges faced by women in STEM.

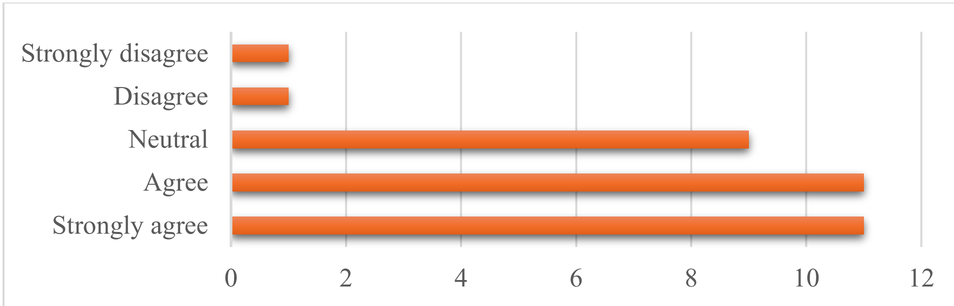

Figure 5. Recognition of Gender Underrepresentation in STEM Fields.

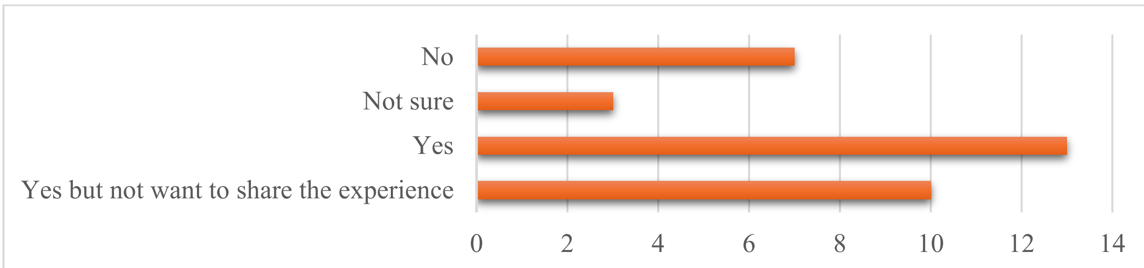

Figure 6. Perceived Gender Bias in STEM: Experiences and Challenges.

Familiarity with emerging technologies
Participants' exposure to emerging technologies is critical. First, in male-dominated fields like architecture and construction, where physical labor historically limited female participation, technologies such as BIM, drones, and automation directly reduce reliance on manual tasks, lowering entry barriers for women. Second, rapid technological evolution demands continuous skill adaptation; tracking women's engagement with these tools reveals their ability to navigate changing industry demands—a key factor in career sustainability.

To explore women's sensitivity to emerging technologies and their perceptions and ambitions regarding industry development, the researchers, under expert guidance and through online resources, identified 15 popular STEM technology fields for this study. Participants demonstrated significant interest in emerging technologies, with over 30% reporting experience or familiarity with tools ranging from well-established systems like GIS and BIM to rapidly evolving AI technologies (see Figure 7). Each participant was familiar with or had explored at least three technologies from the list, with an average familiarity of 6.2 technologies per person.

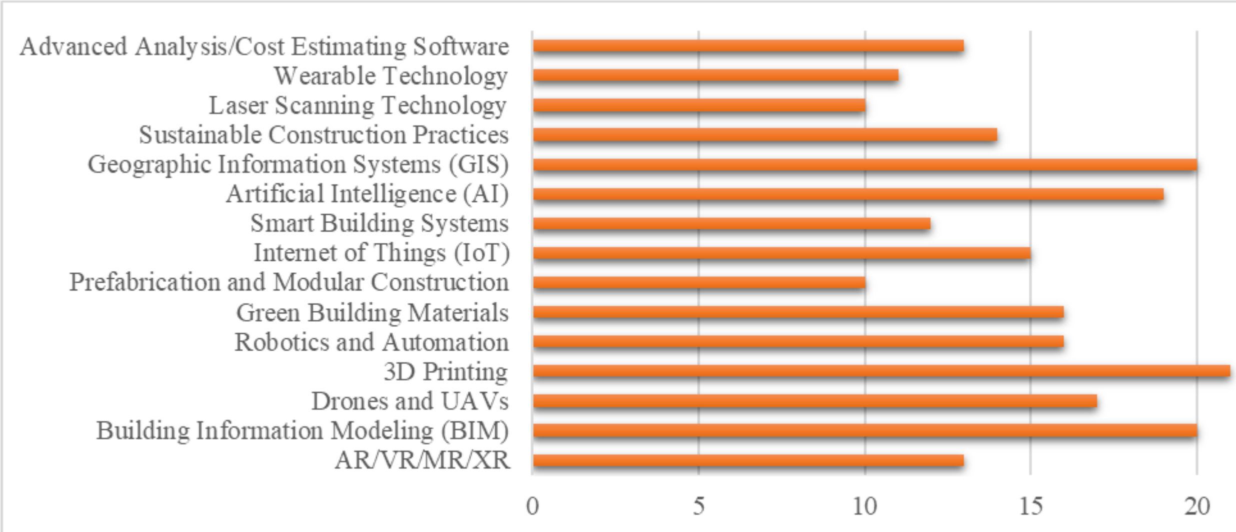

Figure 7. Participants' Familiarity and Usage of Emerging Technologies in STEM.

Core values and workplace concerns
When ranking workplace values, participants prioritized salary, job opportunities, flexible scheduling, company location, workplace environment, and work intensity, (see Table 1). This highlights the importance of caregiving responsibilities and the demand for flexible work arrangements. Interview discussions frequently mentioned gender stereotypes, the lack of role models, and insufficient family-friendly policies as critical challenges.

Table 1. Ranking of Workplace Values and Core Concerns for Women in STEM.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Salary	18	4	3	3	1	1	1	0	0	0	0	0
Location of the company	2	0	1	7	3	1	0	1	0	7	11	0
Workplace environment	1	5	3	2	8	1	0	0	2	0	9	0
Job opportunities	1	8	7	5	4	3	2	1	1	0	0	0
Flexible schedule	3	3	8	2	4	3	7	0	0	0	1	0
Intensity of work	0	7	1	6	2	8	3	3	1	0	0	0
Social status	1	2	1	4	5	5	5	5	2	0	1	0
Size of the company	0	0	0	2	3	3	8	5	6	3	1	0
Company culture	4	1	3	1	0	2	2	9	4	4	1	0
Percentage of women	1	1	1	0	1	0	0	6	10	9	2	0
Number of female leaders	0	1	3	1	0	4	3	1	5	8	5	0
Other	0	0	0	0	0	0	0	0	0	0	0	31

Recommendations for attracting and retaining women in STEM
Through in-depth interviews, participants shared valuable recommendations for attracting and retaining women in STEM. The most frequently mentioned suggestion was the need for mentorship and sponsorship programs to provide guidance, career support, and role models. Participants also emphasized the importance of raising awareness among women about industry developments and career prospects, along with expanding access—particularly through more

flexible educational formats—to training opportunities. These strategies can help women build confidence, stay competitive, and better navigate the evolving STEM landscape.

Discussions

This study offers critical insights into the systemic barriers faced by women in STEM, providing empirical evidence that both supports and expands existing theoretical frameworks. Additionally, it outlines educational strategies aimed at advancing gender equity, including mentorship programs, institutional policy reforms, and inclusive curriculum adaptations. It is important to note that the findings of this study are grounded in the experiences of women in architecture and related engineering fields. While some challenges (e.g., gender bias, work-life balance) may resonate across STEM disciplines, others (e.g., physical labor stereotypes) may be more context-specific.

As technological advancements continue to transform labor-intensive industries, innovations such as remote support systems and intelligent robotics are reducing the physical demands traditionally associated with STEM roles. This shift not only opens pathways for broader participation but also challenges stereotype-driven barriers that have historically deterred women from these fields. Yet, despite these advancements, the findings reveal persistent inequities, emphasizing the need for targeted reforms in both educational and professional environments.

The participants' reports of gender bias, salary disparities, harassment, and emotional isolation reflect inequitable distribution of resources and opportunities in STEM workplaces. These findings align with the Gender Equity Theory's emphasis on the need for structural changes to dismantle systemic barriers. For instance, the lack of women-friendly facilities and limited inclusion within teams, and the frequent questioning of women's technical competence highlight how male-dominated workplace cultures continue to perpetuate disparities. The findings emphasize the urgency of structural reforms such as inclusive policy adjustments, anti-harassment training, and workplace mentorship programs tailored to support women's advancement.

Additionally, our findings suggest that women in STEM face multifaceted challenges that extend beyond gender alone. The experiences of bias and exclusion reported by the participants align with the Intersectionality Theory that intersecting identities—such as race, ethnicity, and socioeconomic status—may exacerbate disparities. Women of color interviewed in this study reported facing both racial and gender biases, amplifying their professional challenges. These results call for more targeted interventions such as mentorship and sponsorship programs that address the unique needs of diverse groups, recognizing the compounded effects of multiple marginalizations.

Our findings also reveal that while the participants demonstrated significant interest in emerging technologies and familiarity with multiple tools, their pathways into STEM careers were often delayed compared to their male counterparts. With 65% of participants indicating they first considered STEM careers only after age 19, this delay may reflect a lack of early self-efficacy and exposure to STEM opportunities, as Social Cognitive Career Theory suggests. Participants frequently linked this delayed career consideration to the absence of positive role models and limited access to early career exploration opportunities. The participants' reliance on online resources and professional associations to learn about STEM careers highlights the importance of accessible, flexible educational formats to build confidence and support career aspirations. However, barriers such as unsupportive environments and minimal use of college career services may hinder long-term persistence. Therefore, mentorship and career workshops that frequently recommended by participants would emphasis on the importance of social and environmental support in fostering positive career outcomes, which were the most frequently cited sources of career information among participants as well.

Lastly, the participants prioritize flexible scheduling, workplace environment, and caregiving responsibilities highlight the influence of value-driven career decisions. Women's preference for family care giver aligns with the Expectancy-Value theory regarding how values and expectations would shape career choices. Additionally, the finding that formal consideration of STEM careers often begins after high school or college suggests that sociocultural influences, such as gender stereotypes and lack of early exposure, may discourage women from pursuing STEM during formative years. This result reveals the importance of early interventions, such as K-12 STEM education initiatives, hands-on internships, and career exploration workshops, are critical to shift these sociocultural dynamics and foster career aspirations during formative years.

One significant methodological contribution of this study lies in its mixed-methods design, which combined surveys and follow-up interviews. The survey captured broad patterns of gender bias, career barriers, and technological engagement, while the interviews provided deeper insights beyond the initial data points. Several participants disclosed sensitive workplace experiences, such as harassment and emotional isolation, only during the more relaxed interview setting, highlighting the importance of qualitative follow-ups in uncovering nuanced challenges that might be omitted from formal written surveys, even when anonymized.

Implications

For educational institutions

Educational institutions play a pivotal role in addressing the delayed entry of women into STEM fields. To counter this, gender bias awareness and early STEM career exploration should be introduced earlier in K-12 education, ensuring more young women are exposed to STEM career possibilities during formative years. Additionally, the curriculum should emphasize the application of emerging technologies in engineering, particularly tools that reduce physical labor demands, such as remote-controlled equipment, mechanical control systems, and intelligent construction tools. This exposure not only aligns with technological advancements but also helps break the stereotype that STEM roles require heavy physical labor, potentially deterring female participation.

Furthermore, harassment recognition and prevention education should be integrated into early education, with content designed for all students, not just women. Schools should offer professional guidance on harassment response strategies, ensuring students are equipped with knowledge of reporting mechanisms and support channels. Expanding partnerships with professional STEM networks and organizations through online panels, virtual lectures, and mentorship events can inspire more young women to explore STEM career pathways actively. Additionally, university career services should be strengthened to better connect students with successful women in STEM fields, offering personalized career counseling and networking events tailored to women's unique career challenges and aspirations.

For workplace

One key finding, consistent with prior research, is that women often struggle with work-life balance due to caregiving responsibilities, leading to career compromises such as adjustments in job location, schedule flexibility, and work intensity. Many participants in the interviews acknowledged that this plays a significant negative role in women's long-term career ambitions and development. The workplace must prioritize inclusive practices and policies to retain women in STEM careers. Family-friendly policies such as flexible work arrangements and parental leave should be standard, along with the establishment of mentorship and sponsorship programs that provide women with career guidance and advocacy throughout their professional journeys. Regular diversity and harassment training for all employees, not just women, should be implemented to create a safer and more equitable workplace culture. The study also highlighted persistent workplace harassment concerns, reinforcing the need for proactive educational efforts and clear, well-enforced anti-harassment policies.

Limitations and future study

Future studies should aim for larger and more diverse participant samples to validate and extend these findings across various STEM disciplines, such as biotechnology or computer science, in order to develop comprehensive gender equity strategies. Adhering to in-depth forms of qualitative research, such as more in-depth interviews, can help explore sensitive workplace experiences and challenges that women may be reluctant to disclose in public. In addition, incorporating cross-correlational analysis could provide a more refined understanding of how multiple factors interact to contribute to the underrepresentation of women in STEM. Furthermore, further investigation into the direct impact of mentorship, institutional policies, and evolving career pathways can provide more nuanced insights into how structural changes influence career sustainability and long-term retention for women in STEM. Moreover, examining how factors such as ethnicity, educational background, and socio-economic status intersect with career challenges could offer deeper insights into the diversity of experiences within these fields and inform more targeted support strategies. To support future research efforts, we also plan to make anonymized data available for further analysis.

Conclusions

In conclusion, this study offers meaningful insights into the challenges and opportunities faced by women in STEM, emphasizing the need for systemic changes across educational institutions, workplaces, and policy frameworks. Its findings provide evidence-based recommendations, including early STEM career exposure, mentorship, inclusive policy reforms, and proactive harassment education. By creating more supportive learning environments, expanding access to modern technologies, and strengthening career services, stakeholders can collectively work toward attracting more women to STEM fields and ensuring their long-term success in the industry.

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