AI's Visual Representation Gap: Redefining Civil Engineering Workspaces for Early-Career Women

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Division: Engineering Leadership

Abstract
Engineers, predominantly visual thinkers, have historically encountered engineering workspaces designed by men, for men. This trend continues, evident in the underrepresentation of women in the engineering sector. Contrary to the belief that women's departure from engineering is due to changing interests, many feel marginalized within many engineering environments.

In examining the representation in 100 AI-generated images of "engineering workplaces," 31 images included human "engineers." Disturbingly, all the depicted engineers were White males, with absolutely no representation of women. This illuminates the prevailing bias in AI interpretations, presenting engineering as a male-exclusive domain. To challenge this narrative, this study ventured to produce images inspired by descriptions from women at the onset of their engineering careers. It endeavors to explore the idea of inclusive engineering environments conceived by budding women civil engineers and to highlight strategies for creating more inclusive engineering imagery.

This initiative is a part of a broader qualitative narrative study, focusing on the stories of seven early-career women civil engineers (within their first 0-4 years professionally). Data was amassed through diverse methods, including semi-structured interviews, field observations, reflective diaries, and AI-generated illustrations of participants' dream workplaces. The research underscores the essence of inclusive engineering environments, championing the creation of participant-inspired spaces via AI visualizations. Findings reveal that these women picture their optimal engineering spaces as vibrant, lively, and cooperative havens. Alongside advocating for open-concept designs over the conventional walled cubicles, there's a unanimous call for nurturing zones featuring scenic views, rest areas, and wellness amenities like nutritious snacks and greenery. The study also suggests that with more flexibility, robust mentorship, consistent feedback, comprehensive performance reviews, and a better work-life equilibrium, early-career women engineers might find a more sustainable career path in engineering.

Emphasizing the visual elements that advocate for the inclusion of women engineers, this research has ramifications for recruiting and retaining talent, aiming to reshape engineering work environments and amplify diversity. It sheds light on the inherent bias in popular AI models and introduces AI-generated visuals of potential inclusive spaces for women engineers. The implications are far-reaching, involving all parties associated with the conception, construction, upkeep, and leadership of more inclusive engineering spaces. By adopting broader and more diverse perspectives to workplace and AI algorithm development, women engineers can more fully experience the notion that “if you can see it, you can be it".

Introduction

Countless national reports and publications have identified the challenges associated with the persisting lack of diversity or “missing millions” (i.e., the lack of women, Black, Latinx and other historically underrepresented groups in science and engineering) within engineering [1]. Despite efforts to improve the representation of women and those of underrepresented identities in engineering, the inclusion and retention of women in these spaces remains low [2]. Civil engineering as a discipline specifically struggles with large turnover rates and low representation of women [3].

Civil engineers are often visual thinkers, designing and constructing the buildings of the future. However, women entering these spaces have historically encountered engineering workspaces designed by men, for men. Contrary to the belief that women's departure from engineering is due to changing interests, many feel marginalized within engineering environments [4], [5]. To address this issue of masculine environments and “chilly climates” that continue to push women out of these spaces [6], [7], [8], this work seeks to develop narratives of what more inclusive spaces for women in engineering would look and feel like.

The design of engineering workspaces is one of many decisions that engineering leaders must make. Leadership plays a critical role in ensuring successful recruitment and onboarding of talent, cultivating inclusion, productivity, innovation, and reducing turnover. Inclusive leadership can enable organizations to tap into the advantages of today's diverse and globalized workforces, achieving a better balance between business priorities and engagement with people of diverse identities[9]. To advance the inclusion of women within engineering spaces, engineering leaders

must be intentional about the design of workspaces and cultures to promote inclusion of everyone on the team. Inclusive leadership requires challenging the status quo, fostering innovation, and proactively embracing diverse perspectives to enhance overall inclusion and foster a sense of belonging [10], [11].

This work seeks to expand our understanding of how to best support and retain women in civil engineering spaces through inclusive leadership. Specifically this work focuses on civil engineering spaces (i.e., physical work environments) and cultures (i.e., shared values, beliefs and attitudes that shape social interactions within and outside of the workplace; [12]) and how they could be improved to increase the inclusion and retention of women in engineering.

Background

Early-Career Women in Engineering

Understanding the experiences of early-career women entering the field of civil engineering is crucial for comprehending the broader challenges of exclusion and attrition faced by women in civil engineering careers. The initial years in a new position or during internships play a pivotal role in shaping the career trajectory, influencing women's decisions to persist or exit the profession [13]. Research on the socialization process of newcomers to STEM careers underscores the significance of early-career experiences, emphasizing their impact on job satisfaction, expectations, and goals [14], [15], [16]. Despite being a critical juncture where individuals often contemplate industry departure, early-career experiences have historically been understudied [17].

Over the past decade, more scholars are delving into the experiences of early-career men and women in engineering or STEM more broadly. In a comprehensive 2016 study analyzing thousands of diary entries to explore the professional socialization of engineering newcomers, it was found that internships solidified men's commitment to the engineering field, while women began to question their intentions to pursue a career in engineering [18]. A 2022 study situated in computer science explored women's internship experiences and intentions to persist in a computer science career; findings from this work indicated that "navigating gendered microclimates" was a challenge these women faced as being one of the only women on their team [19]. Additionally, a 2017 study on socially engaged engineers' career interests and experiences raised concerns about potential career disillusionment for women in engineering [20]. This research highlighted that women engineers' career expectations (e.g., that engineers will perform meaningful socially engaging work similar to their experiences in Engineers Without Borders or other service organizations) may not align with the realities of their industry [20]. This misalignment of expectations and reality can result in dissatisfaction and a loss of interest early in women's engineering careers [20].

Inclusive Leadership in Engineering

Inclusive leaders are essential in facilitating inclusion in relations in the workforce [21]. Inclusive leadership can be impactful for the inclusion of women in male-dominated spaces (e.g., engineering). Leaders can seek to become inclusive leaders by educating themselves and others on the challenges and barriers women may face and seeking to empower women on their team and help them to identify career growth opportunities [21]. Research indicates that individuals feel a sense of inclusion in the workplace when they experience both a sense of belonging and

feel valued and appreciated in the uniqueness of their identities [22]. There is a growing body of literature on inclusive leadership development, yet more can be done to improve leadership that is inclusive to women [9]. Thus, to improve the inclusion of women in male dominated spaces such as engineering, and reap the numerous benefits associated with gender inclusion, practicing inclusive leadership is essential. Leaders in engineering organizations play a significant role in shaping work spaces, environments, policies, cultures, values, and social norms [10]. It is essential for inclusive leaders to be mindful of the cultures they are perpetuating and seek to develop a culture of belonging where all individuals, regardless of identity or privilege, believe they can thrive [10].

Inclusive Cultures

Workplace cultures and environments can greatly impact performance, productivity, efficiency, teamwork, communication, collaboration, job satisfaction, employee engagement, stress, and burnout and even retention [12]. The scholar Schein indicated that culture can be broken down into various levels including artifacts (i.e., visible structures and processes of an organization), values (i.e., beliefs, and philosophies, why they do what they do) and underlying assumptions (i.e., unconscious beliefs thoughts and feelings) [23]. Organizational culture can help individuals and groups make sense of an experience, reduce individual anxieties, and can even help foster belonging and acceptance and a sense of shared identity [24]. However, if these cultural artifacts, values, and underlying assumptions only benefit certain groups, it may result in exclusionary practices for others. Leaders play a pivotal role in shaping cultural norms and facilitating change. Schein emphasizes that organizational change extends beyond surface level changes and requires exploration of deeper cultural and structural transformations [24]. He recommends leaders strive to foster positive, trusting relationships with their workers through humble inquiry to improve upward communication, which is crucial for addressing complex challenges within organizations [25]. A large review on the literature on inclusive cultures presented a model for building inclusive culture in the workplace[26]. The model outlines how a commitment to and focus inclusion from leaders and management, commitment to inclusive practices (i.e., psychological safety, involvement in the team, feeling respected and valued, influence on decision making, authenticity, recognizing, honoring, and advancing of diversity), accompanying inclusive policies and management of microaggressions, can help foster more inclusive climates [26]. Inclusive climates as well as individual perceived inclusion can ultimately improve retention [26].

Inclusive Spaces or Environments

In addition to workplace cultures heavily shaping inclusion and retention, the physical spaces or environments in which they operate can be very impactful. Inclusive design processes can result in spaces that are more accessible and inclusive to everyone (i.e., those with physical disabilities, sensory imperilments, or with varying needs). A 2023 study in Ireland outlines the impact on inclusive design of engineering classroom environments to make these spaces more accessible and inclusive to all [27]. This work highlights that inclusive design can result from a diverse group of engineers recognizing and respecting human uniqueness and variability, adaptation, and codesigning with underrepresented groups [27]. However, this poses a contemporary challenge as fostering more inclusive design practices for the future requires the engineering workforce (or those involved in design) to operate within inclusive spaces and reflect diverse individuals. Inclusive design aims to tackle the social issue of creating environments that accommodate the

people of diverse capabilities [28]. To achieve this goal, it is crucial to involve a diverse and underrepresented individuals in the design processes to comprehensively assess what works and for whom [27], [28]. The U.S. Green Building council even outlines practices for implementing inclusive design of spaces including the following recommended spaces: improve physical access beyond federal, state, and local requirements, provide amenities like quiet, wellness, or meditation room(s), all-gender and/or family restrooms, exterior green space, public restrooms, public education areas, publicly-available event space, indoor weather shelters, fitness spaces with accessible and inclusive activities and equipment, and spaces that encourage frequent, casual social interaction to reduce probability of social isolation [29].

Inclusive Spaces and Cultures in Engineering

Promoting inclusive cultures within engineering environments is of critical importance to society, especially considering that these professionals play a key role in advancing inclusive design. Without inclusive and representative workspaces that reflect diverse individuals, the progress in inclusive design practices may face significant challenges. Current engineering spaces and cultures are largely representative of White-male settings, values, and norms [30]. The engineering culture has often been described as chilly, isolating, exclusive, and even hostile towards women throughout the body of literature [18], [20], [31], [32], [33], [34]**.** Findings from this work emphasize the importance of cultivating more inclusive cultures in engineering education especially for women and those of underrepresented identities [6], [35], [36]. Civil engineering and construction sectors specifically struggle with retaining women and in perpetuating a culture that is often exclusive towards women [37], [38], [39]. In a study of women working in the construction sector, the authors found that the top challenges encountered in the workplace were stress, difficult work-life balance, negative perceptions of women in construction, and long working hours [40]. A study of women civil engineers working in the construction sector in the UK found that women's success seemed to hinge on fitting into the prevailing masculine culture, which values long working hours and social gatherings in male-oriented pubs [39]. Companies without welcoming and inclusive environments see more women leaders leaving their positions [41]. This not only prevents qualified individuals from progressing in their careers because of their gender but also forces them out of consideration altogether and reduces the representation of women in these spaces [41]. There remains a need for research to provide practical, actionable ways on how to facilitate more inclusive cultures for women.

In recent years, there has been an increase in scholarly literature discussing inclusive engineering spaces and cultures within the academic and professional spheres. The national calls from NSF [1] have made it imperative to work towards cultivating environments that foster diversity, equity, and inclusion in engineering. The current body of research in this field emphasizes the importance of dismantling barriers that impede the full participation of individuals from underrepresented groups in engineering education and workplaces. A more holistic understanding of what inclusive cultures and spaces might look and feel like requires input from more early-career women in engineering.

Generative AI

Generative Artificial Intelligence (Generative AI) is a form of artificial intelligence that can generate text, visual images, pictures, or other media using generative models trained using large datasets. Given the rising presence of AI and generative AI across, social media, schools,

academia, personal devices, and recruitment/hiring in the engineering industry, we conducted an exploratory investigation to determine how popular, large generative AI algorithms (i.e., Magespace, Canva, Midjourney, and DALL・E) were currently conceptualizing and depicting engineering workplaces. In examining the representation in 100 AI-generated images using the prompt "engineering workplaces," 31 images contained human "engineers." Disturbingly, all of the depicted engineers were White males, with absolutely no representation of women. This finding illuminates the prevailing bias of engineering workplaces as male-exclusive domains that is seeping into our AI algorithms and perpetuating the notion that women are not included in these spaces. A sample of the generative AI images of "engineering workplaces" is shared in **Figure 1**. In addition to the images generated representing engineers as exclusively White and male, they also depict engineering workplaces as consisting of gray or muted colors, unorganized, cluttered with various parts and machinery, dimly lit, often isolating (one individual sitting alone at a desk), and little access to fresh air.

To characterize the interpretations of this visual data, alternate text was generated for these images using Microsoft Word. These descriptions included, "A group of men sitting at a desk in an office" or "A person sitting at a desk in a room with many objects". These depictions are consistent with the engineering culture that prioritizes technical engineering abilities, the engineering "boys club," and male-associated color patterns and paraphernalia, perpetuating the stereotype of engineering spaces as masculine environments where women do not belong. These images not only raise concern about what kind of existing biases have seeped into AI algorithms and models but also contribute to generating more problematic images of engineering culture that perpetuate the lack of women in these spaces. Additionally many of the elements of these images (e.g., lack of diversity, isolation, disorganization, staring at a screen all day, and chaotic, closed, dark environments) are not attributed to increased productivity or performance for anyone [42]. Images such as this may be exactly why women have historically felt pushed out or "chilly" in such environments.

Figure 1. A sample of the generative AI images of "engineering workplaces"

It is important to note that because many generative AI models are relatively new there is much discussion around the bias that may be present, suggesting that more detailed prompts should be used to mitigate this. It is still essential to understand exactly what the implications of these biases may be. Should a curious high school student generate an image of an engineering workspace and find images depicting all White men in gray and cluttered settings, they may feel that space is not inclusive and shift career interests. As we remain uncertain about whether the bias resides within the AI models or stems from the training data used in their development, it is crucial to strive for the creation of more inclusive imagery throughout visual AI platforms depicting engineering spaces. Furthermore, as AI algorithms are integrated into recruitment and hiring practices, it begs the question of what existing data the algorithm would pull from to determine who the most suitable candidate for the job is. If prior data suggests that engineers are all middle-aged White men, and generative AI platforms across the board are depicting them as

such, what might that mean for someone of a different race, gender, or ability status in an AI-evaluated interview?

To challenge this narrative, this study ventured to produce images inspired by descriptions from women at the onset of their engineering careers. We explored the idea of inclusive engineering environments conceived by budding women civil engineers to uncover strategies for creating more inclusive engineering imagery. In addition to examples of generative AI images and more inclusive generative AI prompts, this study offers recommendations for enacting inclusive engineering leadership to facilitate inclusive workplace spaces and cultures to improve the retention of early-career women.

Workforce Sustainability Model

Utilizing the Workforce Sustainability Model as a conceptual framework, this study delves into the examination of inclusive spaces and cultures within civil engineering. The Workforce Sustainability Model, a validated tool, serves to characterize and evaluate the sustainability and inclusivity of a civil engineering or construction workforce [43]. As articulated by Gambatese et al., the pursuit of workforce sustainability involves not only the recruitment of highly skilled and competent individuals but also the creation and maintenance of an environment conducive to their well-being. The model establishes a comprehensive framework encompassing key attributes, indicators, and metrics to measure workforce sustainability, including:

- Nurturing - the degree to which an employee feels supported, encouraged, educated, and cared for as an individual
- Diversity - the degree to which the workplace is diversified and inclusive), equity (the degree to which a worker feels fairly treated, evaluated, and compensated without discrimination
- Health and wellbeing - the level of health, safety, and contentment experienced in the workplace, career, and beyond
- Connectivity - the extent to which workers feel engaged and connected to others and involved in decision making
- Value - the degree to which workers feel valued, appreciated, recognized, and respected
- Community - the degree to which workers feel accepted by, share similarities with, and have camaraderie with others in their organization or industry
- Maturity - the extent to which a worker gains leadership competencies and responsibility or accountability in their position [43]

Originally devised as a quantitative survey for assessing a workplace's ability to sustain, retain, or include workers [43], this research repurposes the model to function as a lens for the qualitative analysis and coding of early-career women's narratives and AI-generated visual data. The objective is to understand the critical attributes that can enhance the inclusivity and sustainability of early-career women in civil engineering, thereby offering a nuanced understanding beyond traditional quantitative assessments.

Positionality

As is typical in qualitative research, the researchers' identities and connection to the participants played a significant role in shaping this study, research design, data collection, and analysis. The first author identifies as a White, able-bodied, cisgendered woman who is also an early-career civil engineer. The second author identifies as a Black, cisgendered woman with experience in

both engineering and construction industry and academia. The first author's position and involvement in multiple civil engineering internships, academic institutions, mentorship roles, and professional societies allowed her to relate to and recruit women to participate in this study. The first author was able to use her shared experiences and rapport with the participants to establish an environment of trust where participants felt comfortable diving into some of the deeper, personal questions and sharing their true experiences and feelings in interviews. While the first author's close relation in age, gender, and position to the participants aided in collecting rich data through site visits, qualitative interviews, diary entries, and AI-generated images, the first author acknowledges that her identity and experiences also differ from those she studied. The first author acknowledges her privilege in terms of her race (i.e., operating as a White woman in predominantly White spaces) in civil engineering. She understands that due to intersectionality one's identity and experiences are a result of interconnected social categorizations such as race, class, and gender [37]. The first author made an effort to continually consult with the existing literature and the participants (via member checking), and peer debrief with the second author and other graduate students in her lab (a Black man and Black woman) to ensure trustworthiness of the findings.

Research Question

What do inclusive engineering spaces look and feel like to early-career women in civil engineering?

Methods

This exploratory research is a part of a large qualitative study following the narratives of early-career women in civil engineering. The larger project involves initial and (4 month) follow-up semi-structured interviews, written and/or audio diary reflections, and member checking of participants' stories. At the end of the first interview, participants were asked to collaborate with the first author over Zoom or in person (depending on geographic region) to describe their ideal engineering workplace and develop prompts to generate an AI image of their ideal workspace.

Participants

All participants in this study identified as early-career (i.e., within the first 0-4 years in their careers, as four years of engineering experience is what is typically required to earn professional licensure in civil engineering) women entering civil engineering careers at large private engineering consulting firms in the southeastern region of the United States. Participants were selected through convenience and snowball sampling of the first author's industry network and connections and their referrals. Throughout this study, we recognize the concept of intersectionality, where the convergence of various identities may significantly influence an individual's experience. It is important to acknowledge that one's experience cannot be solely attributed to a single aspect of their identity.

Pseudonym	Race / Ethnicity	Major	Job Title	Experience
Brittany	Black / Not Identified	Civil Engineering	Civil Engineer	2 internships, 1.5 year fulltime
China	Black/African American	Civil Engineering	Civil Engineer	1 internship, 6 months fulltime
Kelsey	White / Caucasian	Civil Engineering	Surface	2 internships, 1

			Water Engineer	year fulltime
Sam	Not identified/Caribbean/Trinidadian	Civil Engineering	Civil Engineer	1 internship, 1 year work
Sandy	Black / Caribbean	Civil Engineering	Civil / Traffic Engineer	2 internships, 9 months work
Simone Jones	Black / Not Identified	Biological Engineering	Civil Engineer	1 year work
Victoria	Black/African American	Civil Engineering	Civil Engineer	2 internships, 1 year work

Data Collection

Data was collected via initial and follow-up, semi-structured interviews lasting 30-90 minutes. Interviews were conducted in person or over Zoom, recorded, and transcribed verbatim. The generative AI images were generated at the end of the initial interview using the free AI platform, Mage Space. The first author would share their screen or work in person to enter prompts described by participants followed by "engineering workspace" to generate an image. The participants were then asked to review the generated image and suggest changes to the prompts and what they liked and did not like about the image. The prompts were adjusted and images were regenerated until the participant approved them as a final image for their "ideal workspace". This process was audio recorded as a part of their initial semi-structured interview.

Data Analysis

The researchers conducted thematic analysis of the interview transcripts [44], [45], [46]. This consisted of repeated readings of the transcripts [46], [47] and memoing (i.e., an analytical strategy where researchers note their initial thoughts and interpretations to improve contemplation and communication throughout data analysis) [48]. The qualitative data was then coded deductively (i.e., using the workforce sustainability model) and inductively (i.e., allowing emergent codes to arise) in the qualitative research software, Dedoose. Finally, codes were sorted into themes using the process of cutting and sorting to answer the research questions [44], [45], [46].

The researchers also included analysis of visual data into this study. Participant AI-generated images were uploaded to Microsoft Word and alternate text for images was generated using automatic generations. Codes based on researcher notes and alternative descriptions were generated and themes across the images were found using cutting and sorting of codes [46], [49], [50], [51].

Design Limitations

This study is a part of a larger study that employs a qualitative narrative method that seeks to collect rich data and follow the stories of early-career women entering civil engineering. Due to the nature of qualitative inquiry, the participant sample (n) is low. Qualitative research, while valuable in exploring the depth and richness of human experiences, comes with certain

limitations. One significant limitation is the relatively small sample sizes often associated with qualitative research. Unlike quantitative studies that aim for statistical generalizability, qualitative research emphasizes in-depth exploration within a specific context. Consequently, the findings are not meant to be generalizable but may be transferable to similar populations. Future research could explore comparing the early-career experiences and ideal workspace designs of women to those of men entering civil engineering industry. While this study was situated in the private sector of engineering, we suspect some of these findings may be transferable to other sectors of engineering. However, future work could explore how these experiences and inclusive cultures and environments differ across public, private, and government sectors of engineering.

Furthermore, the researchers acknowledge there are more advanced generative AI systems that may result in more robust images. However, the researchers chose to use the free generative AI program online, Mage Space, as it was easily accessible for graduate students and participants. Lastly, the researchers acknowledge the bias that may be programmed into generative AI algorithms. This work sought to illuminate that the biases we see commonly throughout our engineering spaces and other media are also echoed throughout our generative AI algorithms. This work sought to allow early-career women to modify the prompt "engineering workspace" with the intention of designing an image that incorporates more inclusive elements to it. This was done and repeated until participants got their desired image.

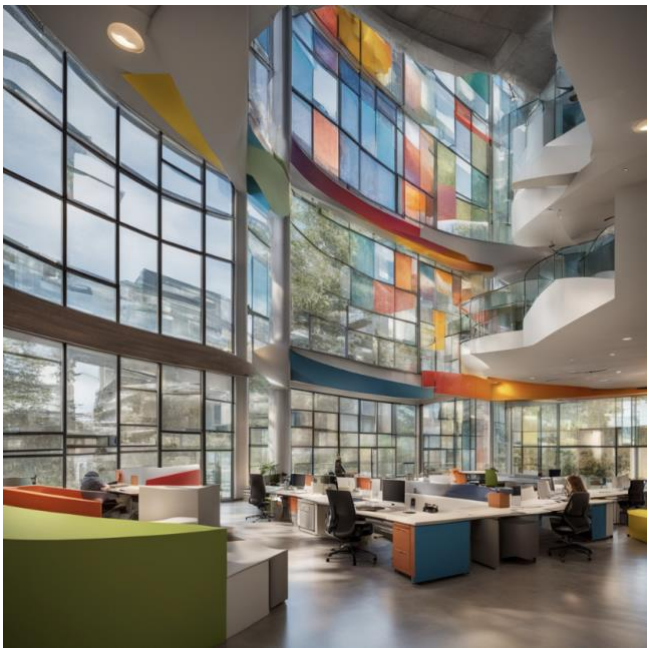
Findings

The following sections present the findings visually in the form of AI-generated images and in writing through the identification of various themes across the interview data.

Participant Designed Generative AI Prompts and Images of Ideal Inclusive Engineering Workplaces

Brittany

Ideal civil engineering workplace description: Not consistently overworked, better work-life balance, able to take more time on a project - simmer on project, give it more attention to detail - not a constant race against the clock, more comradery on team, free lunches /food
Generative AI Prompt: open-concept, cute aesthetic, outdoor element, colorful, fun, clean, separate offices for privacy, communal workspaces for collaboration, engineering workplace



China

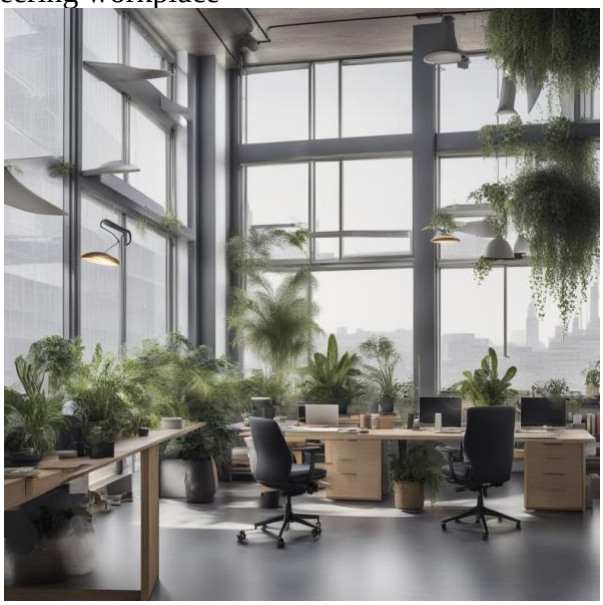
Ideal civil engineering workplace description: Completely diverse, more women, more training, better support for new hires - devoting time to company/team specific training, supportive HR, IT support, more hybrid schedule - work from home days, less stressful environment

Generative AI Prompt: Diverse, fun, inviting, free, welcoming, slide, engineering workplace

Kelsey

Ideal civil engineering workplace description: Clear expectations, organization, higher focus on environmental aspects of design, better teamwork/collaboration, Big open kitchen, nature, nice relaxing views, social, fun, areas to chat and bond with coworkers

Generative AI Prompt: Big open windows with nice view and kitchen, nature, motivated people, social, fun, engineering workplace



Sam

Ideal civil engineering workplace description: Women's support group, free office lunches, more child care and support to have kids, more flexibility, relaxing, nice lunch area, access to healthy food options, snacks around office, colorful - yellow (or other positive colors), happy, include plants/greenery, not gloomy or stressful/depressing

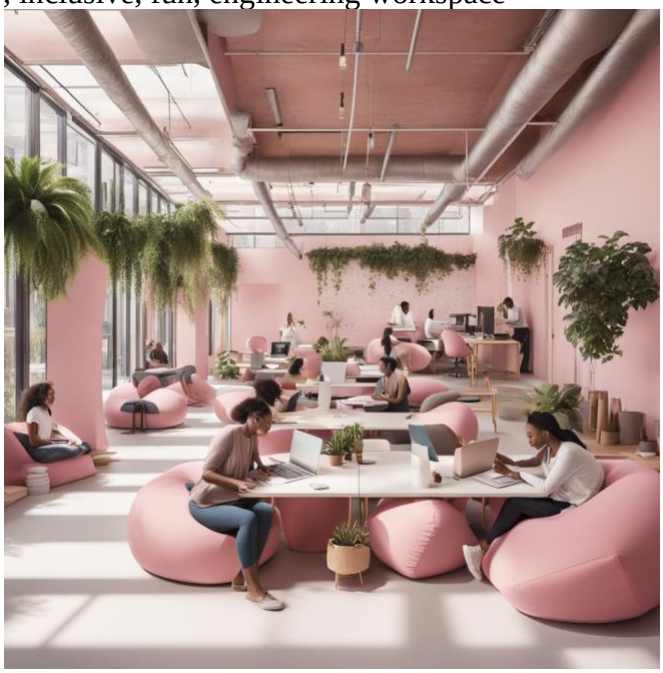
Generative AI Prompt: Relaxing, open, positive, yellow, colorful, plants, engineering workplace

Sandy

Ideal civil engineering workplace description: Flexibility in client success metrics (value more than just time spent on projects), promotes work-life balance, quality of work and competence,

better support for young engineers, values employee health/wellness and happiness, strives for client satisfaction but not at expense of employees livelihood, enjoyable, more flexible, less stress focused, relaxing, diverse, inclusive, more women, more color, inclusive to women, open, light, large windows, more greenery

Generative AI Prompt: Open-concept, light, large windows, relaxing, plants, pink, more women, more diversity, inclusive, fun, engineering workspace



Simone Jones

Ideal civil engineering workplace description: More welcoming environment for newcomers, more professional development opportunities, better technical training - and trainings on specific projects, supportive, more fair/equitable, higher pay, allow individuals to negotiate their own salaries based on experience and internships, more flexible with hours, opportunities to work remotely, more holistic approach, evaluate individuals performance on more than just time reporting metrics, less employee turnover, less overworking employees, genuine work-life balance, no cubicle walls/divisions that separate individuals from their team, more color, nature elements, relaxing views

Generative AI Prompt: Open concept, nature, fun, relaxing, floor to ceiling windows, sunny, natural light, color, fun colorful workwear, welcoming, engineering workplace

Victoria

Ideal civil engineering workplace description: Quiet, diverse, private offices, plants, more teamwork collaboration in areas, kitchen, snacks, wellness areas, teamwork, large windows, “no a**hole policy” - meaning absolutely no tolerance for abuse or disrespect in the office, more encouragement of mentorship and collaboration, reduce evaluation solely based on time spent on projects to promote more mentorship and collaboration, frequent check-ins from leadership with junior engineers - to check in on a personal level, buddy system - assign newcomers a “buddy” to meet with regularly and check in, safe places to express concerns, prioritize work-life balance

Generative AI Prompt: Private offices, plants, more teamwork collaboration in areas, large windows, relaxing views, balanced, engineering workplace

Victoria wanted to include both of these images as the one on the left depicts a private workspace and the one on the right depicts a communal area where workers might meet to collaborate on projects or mentor and support each other

Themes across participant workspaces

Engineering workspaces could draw inspiration from "Tech Spaces" to explore more innovative and "fun" engineering cultures and environments.

Three participants articulated a shared aspiration for their office environment to closely mirror the vibrant and inclusive atmosphere observed in technology offices they have visited or contemplated working in. Simone Jones shared, "I think of how tech spaces are, how there's no really dividing cubicles between people, how there's like floor to ceiling windows with the sun coming in." Here Simone Jones shares that her ideal workplace might resemble that of a newer tech office. Simone was not alone in this desire. Other participants mentioned tech offices specifically and all participants emphasized the importance of prioritizing aspects such as health, fun, collaboration, inclusion, productivity, and an overall lively and engaging ambiance. Their collective desire is for the workplace to be a space where they can authentically be themselves, experience joy, and eagerly anticipate each day. Elements such as natural light, open concept designs, comfortable seating, and vibrant aesthetics were emphasized across all participant designed workspaces. The focus is on breaking away from conventional, sterile, dark, engineering office settings to create spaces that are inviting, fun, and conducive to creativity. The incorporation of more color, inviting communal areas, large windows, more representation and diversity, outdoor elements, fun or relaxing areas, and healthy food options reflects a holistic approach to designing workspaces that prioritize both the professional and personal well-being of employees. When reflecting on her ideal engineering workplace, China shared,

> Honestly, I went to one interview with this [tech] company and they had a slide in their office. I love that just a place where you can live or go work aside from your desk, just a fun little area where it can just be inviting and fun. [...] I would want my employees to just feel free [...] to be free and like be yourself and not be so like square? [...] I would love to incorporate fundraising and just giving back to the community. Or if there's teams that like to go biking or play tennis or do whatever and just really try to make sure that everyone is feeling welcome. [...] Maybe HR can have a little box and just any issue that you might have are things that you would like to change and within the company and just making sure that you're still being heard. If you don't want to talk to them face to face and still kind of be anonymous.

Here China describes her ideal engineering workplace drawing from some elements she noticed when interviewing at a large tech office including fun communal areas with a slide or roller skates and a space where employees felt more empowered to be themselves, express themselves, and be less "square"; incorporated elements of fundraising and giving back to the community; had interest groups to make everyone feel more welcome; and an anonymous way to communicate concerns and feedback to HR or leaders to improve the inclusivity of the engineering office.

Participants described their ideal workplace environments as fun, lively, colorful, and a space for people express themselves. Sandy shared that her ideal engineering office would be, "pretty, like

it would be pink… with a lot of women, a lot of diversity". Similarly, Sam shared that a "colorful office is always nice, like colors that make you [smiles and laughs]. They usually say like yellow makes you happy. Powerful office. With positive colors, I guess. Not gloomy." Sam indicated that colors, especially colors with positive connotations, may help boost the mood and positivity in the office. Simone Jones shared that in her ideal engineering workplace, "everyone's dressed professionally but very expressive, I see a lot of color, like summer colors to keep it fun. I'm not going to say, distract people from the fact that they're working, but makes it more welcoming to it." Simone Jones expressed a desire for a more welcoming workplace where individuals feel comfortable dressing to express themselves. Kelsey expressed a desire for her ideal engineering office to have "big open windows, maybe like a nice view, a nice kitchen, stuff like that. I would want the people to be motivated, but not, like cutthroat. And then, sociable, fun and nice - you know, when you're in the office all day, you kind of end up chatting, so be nice." Kelsey indicated that having nice, sociable people; areas with large windows; and a nice kitchen would be ideal. Sam shared that she wishes that, similar to tech offices, she had, "Access to good food around the office. Healthy food options too."

The participants demonstrated a desire to be able to comfortably meet their physiological and belonging needs, possibly to allow them to stay at the office all day and perform to the best of their abilities. Contrary to the stereotypical engineering workplaces that are depicted as gray/devoid of bright or any feminine associated colors, solemn, somber, and the pressure to conform to the existing masculine norms of the space, participants expressed a desire to see more color and life in the office and facilitate a safe space to express themselves via colorful or feminine clothing and style. The participants suggested that with the addition of natural lighting, pops of color, and a safe space to wear expressive and colorful clothing, they might feel happier and more excited to show up to work everyday.

Early-career women's ideal civil engineering spaces reduce stress and suffering and improve inclusion through prioritizing connectivity, diversity, nurturing, health and wellbeing

The early-career women in civil engineering in this study indicated a desire for careers to be more flexible and have a better work-life balance. Across the interviews all of the women struggled with work-life balance and an extremely demanding workload compared to other industries they had experienced. Additionally, a culture of stress, suffering, and competition over who can work and struggle the most or ignore physiological needs such as eating or sleeping was present in their existing cultures. This added an additional layer of pressure to push past needs and work during what should be time off. As a result, these women indicated a desire for their ideal engineering workplace to focus more on prioritizing connectivity over competition, diversity and representation of other women and mothers at the workplace, nurturing and support for developing in their careers, and a genuine concern and focus on health and wellbeing. Sam expressed that she enjoys when her company does,

> Events outside of work like a Sip and Paint and stuff like that. I really like that part that the women can come together and we just get to know each other. We also have office lunches. Which I also like because I met some of the women in marketing and accounting, who I probably would have never met, even though they're in the same building, but they're like over 200 people here, so that's really nice. [...] I feel like people

> need help when they get older and have their families. Just childcare and having extra hours. Just to pick up your kids from school and stuff like that. So I guess extra time, more flexibility would be nice.

All participants indicated that poor work-life balance and lack of flexibility were concepts they were grappling with as they considered the sustainability of their career. One participant, Kelsey, shared that the underlying culture of suffering and competition made it difficult for her to see herself staying at the company much longer. Kelsey shared,

> This is going to sound like weird, but almost like it's like a virtue to suffer. Almost like it's kind of like a competition to see like ohh like who can stay the latest and like who's like the most unhappy? It's kind of weird I don't know… they're like, ohh, I'm working harder, you know. And like, even though I'm unhappy about it, look how much harder I'm working. There's one guy who is probably in his 70s and he works every weekend, so many hours. And he's always like, 'oh, why weren't you here this weekend?' And I'm like 'cause I don't work on the weekends. Why is this like a weird competition with you?' Also, I'm 23. I don't know. It's just weird. I think that people, it's like an ego thing that maybe people do learn in school and it comes with them.

In order to improve inclusion and sustainability of civil engineering careers, there needs to be a drastic shift in engineering culture that allows for more flexibility and prevents burnout. Participants expressed concerns about the ability to accomplish family and personal goals with limited flexibility and free time at their organization. Sam shared that while her career goal was still to work her way up the ranks of civil engineering, she was concerned about her ability to do this and accomplish her goal of having a family. Sam shared,

> I'm trying to figure out how to do that and with the work-life balance. So when you get older and you have a family, how does that work out. That's what I'm trying to figure out. (pause) …But the goal would be to become a senior civil engineer and win projects and continue in civil engineering.

Other participants indicated concerns around the poor work-life balance in civil engineering careers and some even signaled early signs of burnout in their careers just a few months or years into the job.

Discussion

Understanding more about what works and what does not for including women in engineering workplaces is essential improve the representation of women in civil engineering. Findings from this work align with the broader body of literature on women in engineering and women in the workplace while adding a novel perspective and approach to understanding what elements early-career women would like to see more of in civil engineering workplaces. An improved understanding of women's workplace preferences will aid engineering leaders committed to inclusive leadership as they work to create a more welcoming work environment and culture in engineering.

The Workforce Sustainability Model served as a useful framework for characterizing and assessing the sustainability and inclusivity of civil engineering careers in this study [43]. The women participants in this study emphasized key attributes of workforce sustainability that were crucial for enhancing inclusion and sustainability civil engineering careers as: connectivity, diversity, nurturing, health, and well-being. This study contributes to the existing literature

supporting the Workforce Sustainability Model, which has been validated as a quantitative survey instrument and expands the use of this model to provide a valuable perspective for analyzing qualitative interview data as well [52]. Our findings are consistent with research using the Workforce Sustainability model indicating that early-career engineers, especially Black women, benefit significantly from feeling connected to and supported by their peers and employers [53]. Despite ongoing challenges related to underrepresentation and heightened pressures faced by Black women civil engineers, companies that invest in mentorship and support programs can contribute to their sustainability and retention in these roles, thus enhancing representation and inclusion for future generations of engineers [53].

Scholars in the literature on women in the workplace highlight that there are severe impacts of negative work environments and perceived sexism may result in increased psychological distress [54]. Negative work experiences and increased psychological distress can reduce job satisfaction, which can impact a person's career intentions, performance, mental health, safety, and wellbeing [54], [55], [56]. More specifically, women of color who experience workplace discrimination, including sexism and racism, may be at a high risk of negative job outcomes such as burnout, turnover intentions, and poor mental health [57]. These issues may be heightened by a low sense of fit within an organization and a lack of organizational support [57].

In addition to improving the culture of inclusion and reducing negative workplace experiences, the findings of this work indicate that a poor work-life balance and a culture that promotes suffering and ignores personal needs, is detrimental to retaining women at the early career phase in engineering. The expectation to set aside other responsibilities and work every day imposes undue stress, particularly on early-career women. This pressure may inadvertently expose a broader systemic injustice, highlighting the lack of privilege for women to extend their working hours or dedicate weekends freely. Women frequently grapple with substantial social and caregiving obligations, a burden that surpasses that experienced by men, leading to feelings of exclusion within the industry [58].

Recent literature illuminates the idea of the engineering stress culture (i.e., a culture defined by long working hours, lack of sleep and overworking, struggling, ignoring health or survival needs such as eating, sleeping, or socializing) [35]. While this culture has largely been studied in an academic setting [35], this stress culture very clearly carries on into the workplace. This engineering stress culture may be detrimental to mental health, which may result in higher turnover in engineering industries [35]. Literature in construction, a field that civil engineers often work in or alongside, warns that a culture that praises workers who act as if they do not have a personal life (e.g., boasting about late work hours, lack of sleep, and spending the most time at work) is likely to silence those who raise concerns about the consequences of overworking or the inefficiency of such overworking practices [39]. Research on workforce development indicates that organizations should holistically address employees' wellbeing and needs to achieve the best outcomes in terms of efficiency, productivity, performance, and innovation [59]. According to Maslow's Hierarchy of Needs [60], in order for employees to achieve self-actualization (i.e., to meet their highest potential of creativity, problem solving, and professional-growth) they must first satisfy their physiological (e.g., survival necessities, food, water, sleep, shelter), safety (e.g., secure environment, health, safety, resources), belonging (e.g, social connections, relationships, and community), and esteem (e.g., respect from others,

confidence, recognition, and a sense of achievement) needs. Organizational cultures that ignore this theory are doing themselves a disservice by not allowing employees the opportunity to reach their full potential and are likely setting themselves up for reduced performance, job satisfaction, and retention.

In addition to cultivating a culture around Maslow's hierarchy of needs, engineering leaders should consider ways in which they can design and facilitate workspaces to support their employees more holistically. Findings in this work indicate that early-career women are expressing a desire for workplaces that are purposeful and offer designs that may benefit the entire organization, not just early-career women. Workplace design can impact mental health, productivity, and retention [43]. Larger technology companies have been at the forefront of interior design for promoting employee productivity and satisfaction. Companies such as Google have been using spaces that are sustainable and incorporate elements such as: renovated LEED certified buildings, large open windows and plenty of natural lighting, easy access to healthy snacks and food, collaborative spaces, private desks and offices, plenty of art and color, neutral tones, plants, amenity spaces, fitness rooms, game rooms, cafes, calming views, and areas for "whimsical escape" [61], [62]. The women in this study noted that environments resembling there sort of tech spaces could potentially offer them more support. However, it's crucial to consider the allure of greener pastures in different industry environments compared to their own. Technology and other STEM workplaces frequently grapple with similar issues concerning work-life balance, burnout, and the exclusion of underrepresented groups. Companies have been designing workplaces to facilitate collaboration and innovation by creating spaces that facilitate accidental bump-ins with colleagues and conversations that spark innovation over lunch or fun and games. Workspaces can be designed to reduce stress and the need for employees to leave the office by having quality food and opportunities for socialization and decompressing on site. Physical work environments can also be created that encourage employees to take risks and try new things [63]. Additionally, research conducted on inclusive design of engineering spaces suggested that barriers to inclusive spaces were spaces that have lots of distracting or bustling busy environments, noise, odors, fluorescent lighting, poorly lit areas, and or uncomfortable seating or overall environments [27]. Interestingly, the majority of the original generative AI images of "engineering workspaces" depict busy environments with poor or fluorescent lighting, indicating these designs may hold barriers to inclusion on a number of levels. The incorporation of natural light and a focus on employee health and wellness activities, such as onsite athletic facilities, yoga classes, mental health coaching, and wellness check-ins, have been shown to play a crucial role in mitigating stress and anxiety while enhancing the overall mental wellbeing of employees [42]. Extensive research on workspace design underscores the significance of creating "pleasant and comfortable settings" to improve productivity and wellbeing [42]. Elements contributing to such settings encompass intentional workplace layouts that allow for both private offices and collaborative conference room setups, attention to the pleasing aesthetics, feel, and color schemes within the workspace (with studies favoring white and blue tones for their positive effects) [42], [64]. Additionally, incorporating biophilia, greenery, scenic views, and a modest number of plants on desks; ensuring thermal comfort; maintaining good air quality; and maximizing natural light alongside individual-controlled lighting collectively contribute to alleviating the impact of workplace stress and burnout [42]. In contrast to the original generative AI images of "engineering workspaces", the participant designed workspaces consisted of many of the more inclusive design characteristics outlined throughout the literature. This holistic

approach to design not only fosters inclusion and employee well-being but also promotes increased productivity and engagement.

Implications

This work has implications for engineering leaders in both industry and academia for fostering the inclusion and retention of early-career women in engineering settings. Culturally and socially inclusive practices must be actively implemented to create an environment that supports and uplifts these individuals. Recognizing that the maturation and skill development of employees are integral to enhancing efficiency and productivity, organizations must invest in fostering connectivity, community, and nurturing for early-career professionals. Drawing inspiration from growing cultures in STEM settings, particularly the tech industry, workplaces can incorporate vibrant and relaxing spaces, easily accessible healthy food options, areas that encourage connection and collaboration, and a safe atmosphere for women to express themselves. Additionally, adopting sustainable designs, especially in engineering spaces, aligns with the industry's commitment to designing environmentally conscious solutions. Compliance with requirements such as LEED not only contributes to sustainability but also enhances air quality, lighting, natural views, and overall productivity. To improve retention and reduce turnover, organizations should actively seek feedback from early-career women, embrace inclusive leadership practices, and challenge traditional norms by introducing small yet impactful changes to the physical environment. Furthermore, addressing policy changes and establishing cultural norms that prioritize well-being over rigid time schedules can contribute significantly to fostering an inclusive and supportive workplace.

Conclusion

Civil engineers design spaces to work optimally and safely for the people using them. While it can be argued that the current engineering workspaces work, the question remains, for whom do these workspaces truly work for? To understand how we might improve the retention and inclusion of women in engineering spaces, this study explored early-career women’s ideal engineering workplace designs and descriptions. By engaging in a design activity in a qualitative interview, participants were able to design their own ideal workspaces using generative AI. The results indicated that early-career women in civil engineering were seeking workspaces that offer more nurturing elements, spaces for collaboration, and reduce stress with natural lighting, scenic views, and an increased work-life balance. This study further illuminated that without specific and detailed AI prompts, AI platforms may often depict stereotypical White-male engineering spaces. The findings of this study provide recommendations for creating more inclusive generative AI prompts. Additionally, it offers practical insights for engineering leadership in designing inclusive workspaces and implementing inclusive cultural practices.

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