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Challenging the Notion of the Pipeline Problem in STEM

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ABSTRACT

It is widely known that women are underrepresented in science, technology, engineering, and mathematics (STEM). We have a lack of women who choose STEM careers and women leave these careers at a higher rate than men. Women of color are especially underrepresented and face additional hurtles in building their STEM career. While interventions often focus on increasing female interest and confidence in STEM, my work addresses the lack of research on how STEM recruiting and hiring practices impact female career progression and career decision making (Friedmann & Efrat-Treister, 2023). Through identifying barriers women face during the recruitment process, I seek to break down societal inequities that limit female career progression in technology roles and lead to women feeling insecure about their career prospects despite having confidence in their technical skillsets.

KEYWORDS

women, STEM, career search, pipeline, self-efficacy

I'll just be really honest, since this is research, there's a little bit of imposter syndrome. Like I have a clear record of success in these roles that have always been dominated by males. And it used to not really affect me much, but. I don't know. I'm a bit nervous about my skill set. I don't know. Yeah, I don't know. Maybe you've heard that. Or maybe you haven't. But now you have.

I remember listening to this research participant give voice to imposter syndrome. She was halting in her language and there were long pauses. Throughout the interview, the phrase “I don’t know” was repeated in reference to what she could do to create her path forward in her chosen area of STEM (science, technology, engineering, and mathematics). Like many women I talked to, she talked about her love of technology and engineering and expressed confidence in her skillset, but there was also an expressed sense of hopelessness in how she could actualize her career goals. I felt a kinship listening to this successful, ambitious student talk about imposter syndrome; she was giving voice to something I personally had felt and heard countless times before. And even though it was a common experience, it was also a lonely experience and one that is not often highlighted.

It is widely known that women are underrepresented in STEM, and particularly in engineering and mathematics (National Center for Science and Engineering Statistics (NCSES), 2023). In the past, this was attributed to a pipeline problem (Speer, 2023). The pipeline is a metaphor for how individuals enter the STEM profession, and it has been said that if we had more women enter the pipeline— that is if more women were interested in STEM— we would have more female engineers. More recently, there is an awareness that the pipeline leaks, that women start out with interest in STEM but end up leaving (Speer, 2023), and that because women enter the STEM field from many directions, the pipeline metaphor may be outdated (Cabay et al., 2018). Many interventions focus on increasing and affirming women’s interest in STEM (Friedmann & Efrat-Treister, 2023) or building confidence in ability to succeed in STEM, which is seen to contribute to female persistence in degrees and careers (Fouad & Santana, 2017).

As a former engineer and current career development leader working with graduate students in technical degrees, I knew first-hand that we have more than a leaky pipeline problem. Women do not merely need to stay the course in a pipeline towards technology careers; they also need to navigate a labyrinth of barriers when trying to complete their job search and establish their careers. Eagly and Carli (2007) used the metaphor of a labyrinth to describe barriers women face while navigating towards leadership. The labyrinth metaphor acknowledges that reaching one’s goal is attainable and that barriers exist. Barriers such as having access to a smaller network of referrals to job opportunities, being judged through criteria that is colored by bias and discrimination (which can be related to multiple identity factors, including gender and race), and simply having your identity as a woman not seen as being compatible with the identity of an engineer or technology leader. To dismantle the labyrinth and create pathways for all women in technology, we must first understand the barriers that foster imposter syndrome and prevent women, and especially women of color, from being able to thrive and find belonging in STEM. It is this that drove me towards my educational journey in the EdD.

MY IDENTITY AS A FEMALE ENGINEER

I distinctly remember when I realized that I was not an engineer,

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but rather a woman working in engineering— that I didn't really belong, despite my STEM undergraduate degree and graduate degree in engineering. My first job outside of graduate school was working as an Environmental Health and Safety Engineer at a tech company in Silicon Valley. From the beginning, there were lots of signs that I was 'different' from others, in a way that did not fit in. I worked with all men on my team and many of the jokes or office banter and conversation were stereotypically male. Certainly, an effort was made to include me, but it was hard to feel like 'one of the boys' when there were also pinup calendars showcasing women in toolbelts or when everyone had a hobby that I found unrelatable. I also had a hard time looking like an engineer and dressing the part; for example, finding steel toe boots that were comfortable (not to mention fashionable), or safety equipment that wasn't too big — it felt like I was playing dress-up with an adult's clothing. My company issued jacket (which was required to be worn during emergency response activities) was particularly large on me and came down to my knees with the sleeves far overhanging my arms, as it was unisex and not made for someone of my short stature. All these little things contributed to a sense that I didn't belong, but there was a particular moment where I stopped thinking of myself as an engineer and instead, thought of myself as a female who worked in engineering.

It was an environmental health and safety networking lunch at a hotel restaurant; folks were seated at round tables with white tablecloths — I say 'folks' but in my memory, it was mostly older men. I was late because I had something that held me up at work. A male specialist from my company who reported to me was planning to arrive at lunch on time and said he would save me a seat. As I approached the open seat next to my colleague, the man sitting on the other side of the open spot tapped me on the shoulder saying something like, "Oh miss- can we get some more water at this table? My glass is empty." I remember being confused about what he was saying and why, and then my employee laughed and gently chided the man, "she isn't the waitress, she is my boss!"

That incident was small, perhaps not notable to anyone else, but it marked a change in my self-identity. I had always had confidence in my skill set and ability to fulfill my job responsibilities, but I began to question my place in STEM. Despite my engineering graduate degree and nearly a decade of engineering experience and multiple credentials and awards, I eventually left the engineering profession. For a long time, I believed my career change was because I didn't have enough interest in engineering, it just wasn't right for me. My male colleagues all had hobbies that felt related to engineering— they loved to tinker and build things in their garages, while I liked to craft and knit in my living room. I felt like I didn't belong, I was an imposter whose identity wasn't right for an engineer. While it may be true that engineering wasn't my calling, I will never know because like many women, I was unable to navigate barriers such as imposter syndrome, facing discrimination regarding my credibility as an engineer, and I was pushed out of the STEM pipeline.

BACKGROUND

My situation as 'the only' female engineer wasn't unique 20 years ago when I was starting my career, and it remains a common experience for women today; especially in the mathematics and engineering fields, women- and especially women of color- are underrepresented. In 2022, women accounted for only 28% of the total engineering workforce (National Center for Science and Engineering Statistics (NCSES), 2023), and their relative representation in technical roles has recently declined (McKinsey & Company, 2022). In 2021, only 26% of the computing workforce was female, and only 3%, 7%, and 2% of this workforce were African-American, Asian, and Hispanic women, respectively (National Center for Women and Information Technology, 2022). Female representation in technology careers is lacking despite the fact that women have increased their share of science and engineering degree attainment (National Center for Science and Engineering Statistics (NCSES), 2023). In fact, computing is the only STEM field in which women's representation has steadily declined in the past few decades (Martinez & Christnacht, 2021).

The gender imbalance in STEM has wide-ranging effects, including restrictions on workforce size, innovation, and equity. Even with recent economic fluctuations and workforce cuts in the technology industry, occupations in technology have a lower than national unemployment rate and predicted growth (CompTIA, 2023). Women are necessary to meet the occupational demands of this industry. Gender inclusion is also important for innovation and there are related financial benefits of a diverse workforce (Herring, 2009). Most importantly, the gender imbalance in STEM prevents women from accessing high-paying STEM careers and reinforces existing inequities within the STEM industry and the technology products which are produced. For example, we see gender and racial bias in search engines (Nobel, 2018), which is an example of how a lack of gender and racial representation in the workforce can result in biases and prejudices in products (Nobel, 2018). The lack of female and racial representation in technology workers harms us all.

There are a variety of well-documented barriers in the labyrinth women must navigate in establishing their careers within areas where they are underrepresented such as in STEM. Stereotypes and biases present as barriers, causing women to be evaluated differently (Cabay et al., 2018) or seen as less competent in STEM because of their gender (Carli et al., 2016). This is particularly true for women of color who must overcome stereotypes and biases related to both gender and race (McKinsey & Company, 2022). The lack of diverse representation in STEM increases the stereotypes that women do not belong (Carli et al., 2016). Together stereotypes and the lack of female representation can create the barrier of a chilly environments for women, which can be exemplified in microaggressions, incivility, and other unwelcoming and demeaning cues that are sent to women (Pew Research Center, 2018). Stereotypes may also result in discrimination including facing less salary, receiving less support, and microaggressions (Pew Research Center, 2018). Women with intersectional identities (such as LGBTQ+ women and women with disabilities) report even more discrimination than other women (McKinsey & Company, 2022). Women may also receive unwanted sexual attention and harassment (Pew Research Center, 2018). All of these factors may lead to another barrier present in restrictions in accessing social capital, which means women can face hurdles in using social capital to gain access to career opportunities or gain recognition (Twine, 2018). Here again, women of color can face a double-barrier in how gender and racial characteristics (e.g., stereotypes and discrimination) lead to their increased underrepresentation in STEM, which causes even greater barriers in accessing social capital (Twine, 2018).

It is true that we need more women in the STEM pipeline, however there is a lack of research and attention on how the barriers

above affect diverse female career progression and how STEM hiring practices impact diverse female career progression and career decision making (Friedmann & Efrat-Treister, 2023). In particular, there is a lack of research on interactions students have during their career search and how these barriers push women out or encourage feelings that they do not belong. Recent studies on career search interactions have not been gender specific (Behroozi et al., 2020) and most interventions within higher education focus on increasing interest and involvement in STEM.

MY EdD JOURNEY

Taken one way, my story could be an example of a woman who leaked out of the STEM pipeline, who decided that I didn't belong. But I didn't really have a desire to leave STEM and while I let go of my identity as an engineer, I did not want to (and in fact could not) let go of being a woman in technology. I was proud of my skillset, and I loved the impact that technology and STEM could have on society. Today my work is STEM adjacent — leading career development for a technology graduate school in Silicon Valley and challenging the notion that we have a pipeline problem in STEM. As a career development professional, it wasn't long before I became unsatisfied with helping students and alumni shoulder the burden of belonging and navigate the numerous barriers they faced in STEM careers. I needed to find a way to highlight student and alumni experiences that identified ways we could dismantle barriers and build support structures that help them thrive and fulfill their career goals. I decided to attain my educational doctorate so that I could become a scholar-practitioner and bring to the forefront stories and learnings from women who were pushed out of the STEM pipeline. Stories of women who perhaps felt like it was their fault for not being able to stay the course or that they were imposters who needed to increase their confidence to advocate for themselves and carve out belonging in environments that were structurally not designed for women, and especially not designed for women that had intersectional identities (e.g., racial, disability status, parental status, returning student status, etc.).

As someone who works in leadership and career development, I often feel a need to solve problems— to fix things. While the beginning of my EdD journey feels like a lifetime ago, I remember how I entered the program seeking solutions I could implement or new ideas that I could propose which would empower my students and led to the creation of systemic change in technology career development. In my experience this need to 'solve' or 'fix' is common; when I talk about equity in STEM careers, people want to know what they can do to make a difference and create meaningful change. Everyone feels like they know what the problems are already, they want solutions. To lead with equity can feel like you need to have answers, but the EdD taught me how true leadership means listening and creating space for agency. Rather than being solution focused, I had to be inquiry focused.

When I approach with inquiry, I am open to experiences and viewpoints which are outside of my individual and/or the dominant culture perspectives. Although I am a woman in technology, I do not speak for all women or represent all intersectional identities and experiences. Through my EdD learnings, I developed a constructivist view of knowledge and understanding of how knowledge is shaped into being by humans who are influenced by their environment and context. Because knowledge is constructed by people, knowledge does not represent a neutral perspective – it comes from somewhere (Kincheloe, 2005). Approaching with inquiry means not advancing solutions from my own limited perspective as a white woman who is adjacent to STEM and holds positional power in my role as a career development leader. Instead, I seek to learn from others and work in community to bring forth the unseen and co-create the future together. I found that it was also important to take a critical lens so that I could understand how dominant power and culture can influence the process of knowledge creation, along with what is deemed important and not important (Kincheloe, 2005). The STEM career development processes were created by those in power. My goal was to uplift the ways that dominant power influenced the meaning created by those who are marginalized and how it affected their experiences. For me, approaching with inquiry meant centering the narratives of underrepresented and marginalized women, and highlighting their stories which can pave the direction for the future.

LEADING WITH EQUITY

My dissertation study examined the career search experiences of mid-career female students and recent alumni in an online master's degree focused on data science who were seeking to make a career change into technology and aspired towards roles in leadership. I focused on graduate students, because these students were demonstrating a commitment to STEM by their enrollment in a professional degree where the natural outcome is to take up roles in the related domain. Graduate degrees in mathematics and computer science have seen significant growth in the percentage of women enrolled (National Center for Science and Engineering Statistics (NCSES), 2023). These were women who were already interested and invested in advancing their STEM career; no one had to convince them to stay in the STEM pipeline.

I used a qualitative approach in my study, specifically looking at interactions female students and alumni had with career agents (i.e., recruiters, hiring managers, interviewers). I conducted four semi-structured focus groups and ten interviews, with a total of 18 participants. I sought to include participants who represented diverse intersectional identities, including but not limited to women of color and those of varied socioeconomic backgrounds and geographic locations. This criterion of diverse participants was a priority because the current research on female career progression in STEM tends to prioritize the experiences of white women (Twine, 2018), which then leads to policy and practice recommendations that privilege this population. The study focused on the participants' constructions of reality – participants' views of their own interactions with recruiters, hiring managers, or interviewers – with a goal to accurately picture the participants' experiences and meaning. To this end, I employed practices such as having participants review findings, creating an audit trail, and using rich descriptions to establish trustworthiness.

My research makes several contributions to challenge institutional inequalities and help us dismantle the job search labyrinth for women. First, I identified seven structural factors that may present as either barriers or supports in interactions that women face during the STEM career search (or recruiting) process. Table 1 outlines a brief description of barriers as well as descriptions for the corresponding support that could be adopted in exchange. Having awareness of these factors allows us to audit our recruiting processes, talent development systems, and university career services for the presence of barriers and work towards establishing support structures, thereby dismantling the labyrinth, and creating career pathways. When auditing our systems and seeking to

Table 1. Barriers and Supports that may be present in interactions during the STEM Career Search (Recruiting) Process

Barriers	Supports
Unclear, Misaligned Expectations	**Transparent and Relevant Expectations**
Lack of clarity on expectations on how candidates can successfully move through the recruiting process and/or recruiting expectations feel misaligned to expectations for successful job performance.	Transparent expectations on how to successfully move through the recruiting process; interviewing and recruiting expectations are aligned to what is necessary for successful job performance.
Unclear or Absent Feedback	**Timely and Actionable Feedback**
Subjective or absent feedback during the recruiting process as well as no opportunity to provide feedback on the process.	Specific, timely and actionable feedback is provided during the recruiting process and anonymous feedback is invited from candidates (including rejected candidates) on the process.
Rigid Evaluations	**Holistic Evaluations**
Rigid set of qualifications to evaluate applications and performance during interviews (e.g., direct match to certain criteria such as related work experience and years of experience) and rigid set of qualifications to demonstrate cultural fit.	Expanded criteria used to evaluate qualifications, including considerations for demonstrated potential and transferable experience; evaluations are based on cultural add rather than cultural fit.
Critical Interactions	**Collegial Interactions**
Interactions during the recruiting process are impersonal, lacking in respect, or overly critical.	Interactions during recruiting seek to foster personal connections and a welcoming atmosphere, demonstrating respect and support.
Stereotypes, Biases, & Discrimination	**Equity & Inclusion**
Stereotypes related to gender, race, ethnicity, and other identity-based factors (e.g., microaggressions, usages of biased cultural norms, discrimination in terms of evaluation or salary) are present.	The recruiting process involves regular, ongoing dialogue and reflection around the potential for stereotypes, biases, and discrimination, including how they show up, their effect, and how they can be mitigated.
Lack of Social Capital	**Availability of Social Capital**
There is a lack of access to networks for information or assistance in the recruiting process. Candidates are isolated.	Access is provided to networks for information and assistance in the career search process and referrals are used sparingly.
Lack of Representation	**Presence of Representation**
Lack of gender, racial, ethnic, or other diverse identities represented during the recruiting process. “Chilly” environment pervades and sends cues that women are unwelcome.	Diverse representation is present during the recruiting process, while not tokenizing or overly burdening workers with underrepresented identities. The recruiting process is regularly examined for signs of a chilly environment and seeks to send signals of inclusion.

dismantle barriers and establish supports in career development, we need to keep in mind that women do not all have the same experiences in the career search process. Barriers have different effects depending on a woman’s identity and it’s important to consider processes with the lens of intersectional identities so that we do not end up prioritizing a white female experience and perspective.

My research also adds depth to the Social Cognitive Career Theory (SCCT), identifying how structural barriers that are unique to career search learning experiences can negatively affect female career self-efficacy while STEM self-efficacy relating to STEM learning experiences remains high. In other words, women could have high confidence in their STEM skill set, but lower confidence in their ability to achieve career goals due to the presence of barriers I identified during their job search interactions. Structural barriers during interactions in the job search can lead to lower career self-efficacy and contribute to imposter syndrome. This nuance of considering both STEM self-efficacy and career self-efficacy in SCCT can be used to shift our thinking from needing to develop STEM interest and confidence in women (which can be a deficit frame) towards instead breaking down barriers that push women out and limit their ambitions. We can look at imposter syndrome as a structural problem rather than an individual one. Taken together, my research revealed how structural barriers can be transformed into structural supports during the career search to positively impact female career progression and career choices in STEM, increasing female career self-efficacy and supporting female STEM identity.

Since completing my research, my work has been immediately useful and applicable in my role as a university leader. I have used the findings as an audit for our career programming and processes within the university, to ensure that the impact of our work is meeting our intent. For example, one of the barriers I found in my research is unclear or misaligned expectations that women face in evaluations. In this barrier, women may not understand how they are being evaluated or they may face evaluations that are misaligned to the needs of actual job responsibilities. In this example, we had a resume review process whereby students could submit resumes along with their stated career objectives and receive a review by one of our team members. While we had helpful information available on our website that students could use to learn about best practices in resume writing, my team found themselves identifying the same mistakes repeatedly on resumes. Students were not meeting the expectations of a successful resume. By looking at this process through the lens of potential barriers, I could identify how we were

not providing information that helped students learn the expectations for their resumes. This insight led us to revamp our materials and process to add clarity and consistency. This is a small example, but it shows how taking time to understand how students may interact with our work can present barriers that we cannot predict, and how we can increase overall quality by redesigning the interaction to ensure support scaffolding is place.

My research has also shifted my advice and language when I lead workshops, teach classes, or coach students and alumni. I seek to call out intersectional-identity related barriers explicitly and help students to identify how they can dismantle barriers and build support structures for themselves and others. For example, we recently had conversations around negotiation, but instead of focusing only on teaching negotiation skills, we talked about how negotiation isn't a level playing field and that women of color and non-binary individuals face barriers amplified by intersectional identities. More specifically, women face the penalty of being labeled aggressive when the negotiation, which leads to disempowerment (Dannals et al., 2021). I encouraged students and alumni to find ways to practice allyship in negotiation, such as finding ways to uplift colleagues whose contributions may not be recognized, being transparent during negotiation and sharing information, and being aware of how unconscious bias can influence a negotiation.

Another example is how I discuss the way expectations can feel unclear and how students can ask questions that generate transparency, even in interview interactions. I coach around what to do when you feel expectations might be misaligned and how to engage in conversations which can lead expectations to be revised and made more relevant. Overall, I am more cognizant of taking an asset-based approach when working with students and alumni and cultivating conversations around barriers and how those of us in positions of privilege can serve as allies so that we can lead towards equity and inclusion together.

To create real change, educational leaders must work together with industry. Before starting my EdD journey I had the opportunity to present a workshop on personal branding at Grace Hopper Conference, the largest technical conference for women. It was inspiring to speak to so many women, but also maddening to realize we were working on modifying ourselves to navigate a broken job search system— a career labyrinth designed to sap our confidence and led to imposter syndrome. During my last semester in the EdD program when as I was finalizing my dissertation with my committee, I had the chance to present again at Grace Hopper Conference. This time, I shared the stories of women which highlighted how our community could come together to address transforming barriers into support structures, and lead towards belonging and gender equity. Engaging in events like Grace Hopper Conference gives me the chance to talk with technical leaders, hiring managers, and recruiters about how we can work together to address the challenge of establishing gender equity in areas structured to privilege dominant identities.

LOOKING TOWARDS THE FUTURE

I will never know why I left engineering, but my goal as an educational leader in career development is to ensure that others are able to make purposeful decisions about their career pathways and build their way forward rather than getting stuck or pushed out by structural barriers. The National Career Development Association (NCDA) (2011) outlined in a policy statement the importance of career development, and how work is an essential and protected freedom; NCDA defined work as something "which represents the need to do, to achieve, and to know that one is needed by others" (p. 1). Our goal in higher education career services is to ensure students can engage in meaningful work (National Career Development Association, 2011) and in order to meet this goal, career services departments have evolved over the years from focusing on job placement to becoming dynamic centers providing specialized career development support and meaningful connections to employers (Dey & Cruzvergara, 2014). The EdD has helped me lead with equity and call on other educational leaders to bring forth a further evolution in career services, shifting from helping students navigate existing barriers in STEM recruitment processes and instead seek to work together and break down the career search labyrinth that underrepresented and marginalized students and alumni face in building their STEM careers.

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