# We Are Thriving: Increasing the Number of Women in Engineering

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Abstract

An ongoing focus of engineering education research is on increasing the number of women in engineering. Previous studies have primarily focused on examining why the number of women enrolled in engineering colleges remains persistently low. In doing so, while we have gained btter understanding of the challenges and barriers that women encountered and factors that contribute to such negative experiences, it also, as some scholars have pointed out, has cast a deficit frame on such matters. In this study, we take on a positive stand where we focus on women undergraduate students who not only "stay" but also succeed in engineering programs (that is, our definition of thriving) as a way to locate the personal and institutional factors that facilitate such positive outcomes.

Our initial pilot study involved two female engineering undergraduate students at an R1 university. Each student was interviewed three times. While each of the interviews in the sequence had a slightly different focus, the overall goal was to understand the women's autobiographic and educational experiences leading to their paths to engineering and participation in the engineering project teams. The inductive thematic analysis revealed several primary findings which subsequently played a major role in developing a codebook for the current study. Building upon what is learned from the pilot study, the current study uses a layered multi-case study design involving three institutions: a public/private Ivy League and statutory land-grand research university in the Northeast, a public land-grant research university in the Midwest, and a public land-grant research university in the Southwest which is also designated as MSI/HSI. In addition to the interview method, data collection also contains documents and artifacts. For this paper, we zone in onto the data collected in the first interviews, known as the "life history" where we mainly learn about the women undergraduate participants' personal-familial contexts that contribute to their entry to majoring in engineering as identified by the women themselves.

Preliminary findings indicate that: (1) our participants tend to have supportive families; (2) while all experienced gender biases, not everyone has formed a critical consciousness of sexism; and (3) being able to actually engage by "doing" something and creating a product is key to the women's finding joy in engineering and associating themself with the field/profession. It is important to note that the second interviews, which focus on the educational journey of the participants in relation to engineering identity development and project team experiences, are underway. The ultimate goal for the study is to develop a theoretical framework speaking to a multifaceted model of forces (micro as autobiographic, macro as institutional, and in-between or middle-level as team-based) in shaping women's entry and advance in engineering programs. This framework will recognize the variations in institutional type, resource availability, and structural and cultural characteristics and traditions in teams. It will also use such differences to show possibilities of more versatile ways for diversifying pathways for women and other minoritized groups to thrive in engineering.

Introduction

Most prior research on women in undergraduate engineering programs focuses on women's negative experiences [1, 2]. Such literature, while informative, has failed to yield actual change in the field; women continue to be underrepresented [3, 4]. The purpose of this study is to fill that gap by conducting interviews with undergraduate women who are "thriving" in their programs. Interviews with these women will provide insight into the personal characteristics that help these women thrive as well as information on the culture and policies at their institutions that directly impact the women's experiences. These interviews, supplemented with information from three institutions included in the study, will provide critical information on what allows women to thrive in a male-dominated field. The study aims to change negative conversations around women in engineering, which can further deter women from entering the field, and focus on what can help create positive change and inspire more women to pursue engineering. Increasing diversity in engineering will help all engineers and improve the field by inviting new perspectives and ideas to flourish and, in turn, enriching research and innovation [4, 5, 6].

Background

The literature on women in STEM suggests that while progress has been made [7], gender equality and equity in engineering are still troubled with issues. Ongoing issues include attrition, particularly during the first year of undergraduate studies [8], and sociocultural climate and negative stereotypes, including implicit bias [7, 9]. This can ultimately lead to a "leaky pipeline," or some women leaving the field to an alternate career pathway [10]. Undergraduate women are more likely than their male counterparts to drop out of engineering programs because they may experience diminished performance, sense of belonging, and retention [11, 12]. In addition, there are fewer female role models to follow for engineers who are women, which could lead to a sense of alienation [13]. Researchers found that women's self-efficacy along with confidence and self-esteem tends to diminish during the pursuit of engineering education [14]. While some research points to gender-related factors such as the communication style differences as contributing forces in negatively affecting the acceptance of women in engineering fields [15], many have noted the systemic and structural factors as the root causes for such discrimination and exclusion of women in engineering.

One of such systemic and structural factors is institutional policies and culture. Fox et al. [16] studied 45 institutions that were either successful or unsuccessful in increasing the number of women obtaining engineering degrees from their institutions. They found that these institutions varied on two important topics: (1) identifying what problems within their engineering colleges contribute to the low level of female enrollment and (2) how to address these problems. The less successful institutions focused merely on the numbers of enrollment and retention of women. Yet, more successful programs identified and addressed the specific problems, for instance, noting and addressing the issues with the "weed out" classes and lack of support by establishing peer mentors and incorporating hands-on research experiences [16, 17]. Trautvetter [18] found that obtaining "critical mass," that is, having enough undergraduate women in the program and female professors in the department helps create a more welcoming and less male dominated environment that can facilitate increasing enrollment of women in engineering. However, there is no way to quantify an exact number for this critical mass. Whether it is about "size" or

"specificity" as methods to address gender inequity, it is undeniable that increasing women participation, retention and success in engineering education is not only creating a greater and more diverse talent pool, but contributing innovation, collaboration, and overall performance of the engineering profession [19].

Alternatively, the question is what factors make women stay and succeed. According to Amelink and Meszaros [20], hands-on applications of engineering tend to sustain women's interest in the field for the long term. When women can engage in hands-on activities, they feel more successful and relate more to the engineering community. Furthermore, teamwork experiences of women play a large role in how much they enjoy engineering. In their interview study of 55 undergraduate students, Riney and Froeschle [2] found many of their women participants reported a lack of respect from both peers and professors. They also reported a constant need to prove themselves to male peers. In other words, the study showed that when women feel supported and respected by faculty and their peers, they tend to remain and succeed in the engineering. Similarly, in their five-year longitudinal study, Amelink and Creamer [21] found that respect from faculty, both inside and outside the classroom, correlated with female satisfaction in the engineering major. Having older female role models and a peer mentoring program seems to provide support for undergraduate women and build confidence [18, 20, 21, 22].

When researchers examined women's experiences in engineering project teams, mixed findings were noted. Some claimed increased sense of belonging, engagement, effectiveness, productivity, commitment, and team skills. Others noted the lack of standardization along with ineffective team training [10, 19, 23]. Male and female students may have varying project experiences due to differing levels of confidence, self-efficacy, difficult team dynamics, or inequitable task division [24, 25]. Teams are not immune to the societal stereotype where men are seen as engineering "experts." In these cases, women's perspectives on engineering project teams may not be valued. Women are frequently tasked with "soft-skill" assignments such as organizational roles including taking notes and scheduling [26]. Similarly, while Hirshfield [25] found no statistically significant gender differences in speaking times while on a team, stereotypical gender roles and behaviors were present. Furthermore, women often found themselves have to display more assertiveness and other traditionally associated with the masculinity and rely on more communal influence or approaches to get their voice heard [12]. For male students on the engineering project teams, Keough et al. [27] found they displayed paradoxical attitudes – while they acknowledged that women encounter more barriers and challenges in an engineering program, they believed their own team was gender neutral.

Research Purpose and the Specific Research Question Addressed at This Stage

The purpose of this study is to explore the personal and institutional factors that contribute to women's thriving in engineering. Thriving, as we define it, means that the women not only remain but also succeed in their respective engineering programs. Particularly, we chose to use their taking on leadership roles in student engineering project teams as a clear indicator of that success. This qualitative study is a layered multi-case study involving three institutions: a public/private Ivy League and statutory land-grand research university in the Northeast, a public land-grant research university in the Midwest, and a public land-grant research university in the

Southwest which is also designated as MSI/HSI. In addition to the interview method, data collection also contains documents and artifacts. This paper mainly reports on the findings revealed in the data collected in the first interview. In the "life history" interview, we learn about the women undergraduate participants' personal-familial contexts that contribute to their entry to majoring in engineering as identified by the women themselves. As such, the pertaining research question for this paper is: *What are the life events or autobiographic forces as described by the women participants as instrumental to their entry to their current engineering program?*

Methods

Setting and Participations

This paper includes participants from each institution, specifically four women from the Northeast university, five women from the Midwest university, and six women from the Southwest university. The women from the Northeast were seniors in mechanical engineering and on project teams for 3-4 years, currently in leadership roles. The five students from the Midwest university all held leadership positions at one time on their project team but are not necessarily currently leaders. Their majors included one civil, one mechanical, and three chemical engineers. The women from the Southwest included two women holding leadership positions within project teams. These participants were diverse in terms of their field of study (i.e., two from civil engineering, two from mechanical engineering, one from computer science, and one from electrical engineering), as well as their race (i.e., one Hispanic, one South Asia (Bangladesh), one Southeast Asian and Pacific Islander, one Caucasian, one White and Southeast Asian (Filipino), and one White). It should be noted that the students from the Midwest provide limited racial diversity as the student body is mostly white.

Data Collection

The current study built upon what was learned from a pilot study conducted at one institution. In the pilot study, a series of three interviews was the data collection method. A brief description of these semi-structured interviews is provided herein, and more thoroughly outlined in Liang et al. [28]. The first interview explored the women's personal life and background growing up [29]. The second interview focused on the women's learning and education journey [30]. The last interview was a PhotoVoice interview where the participants were asked to film their day-to-day life in the project teams and explain what the videos were about and why they were filmed. As a community-based participatory action research method, PhotoVoice was used to include the women participants in the research process as to empower, rather than control, them in the study [31, 32]. The current study expands such data collection process to include documents and artifacts that allow the research team to understand the institutional contexts. For the purpose of this paper, only the data from the first interviews across the three research sites are included for analysis. Direct quotes herein are labeled in such as way so that they cannot be tied to a particular institution or student using the following nomenclature: "Code for university. Code for student. Interview number (i.e., 1, 2, or 3)." Note that we have not included direct quotes from all participants.

Data Analysis

Multiple researchers involved in this project coded the interview data in order to ensure high interrater reliability. The team applied a codebook generated using the pilot study data. The codebook was developed by each researcher first creating their own code-book for the same interviews of one participant. The team then reviewed the transcripts and their respective code-books to triangulate common patterns and further vetted out differences for consensus building. The agreed-upon codes were then grouped into categories and then categories were grouped into larger themes. The resulted preliminary code-book was tested out on the second participant's interviews for verification and any modification, if needed.

It is important to note that the data analysis process also did not forbid potential new codes or patterns to emerge as we recognize possible differences across different research sites. New codes or patterns were discussed as part of disagreement-and-consensus building process to ensure consistency across the sites. Generally, the deductive coding method used in this project is based on the system by Auerbach and Silverstein [33]. As this study is ongoing, we continue to consider the preliminary codebook with new data to evaluate the extent which it remains valid for the diverse group of participants. We will finalize the codebook and develop theoretical constructs once all interviews are complete.

Results

Through analyzing the preliminary data, similarities were found between the women who were interviewed. Liang et al. [28] created a thematic passage from these similarities. Evans et al. [34] developed and described how these similarities fell into three broad categories: personal factors, gender roles in the institutions and project teams, and a joy of doing engineering. As noted above, this paper utilized the data of the first interviews which had a specific focus on the participant's life history, as such, findings do not speak to all these noted categories. Overall, the data revealed several major themes related to the participants' families, past events and autobiographic circumstances that have planted seeds for interests in STEM. These themes support their later choice of majoring in engineering, their awareness of gender generally, and gender awareness relative to engineering.

> *A. Family plays an important role in shaping the women's journey to engineering and molding their characters, dispositions, and understanding of gender.*

All of the women participants had families where parents were involved and supportive in their lives, but never overbearing. The parents provided resources to help support the women, but never told the women they had to do anything. While some women had a parent or other family members who were engineers, their choice to engineering was self-driven. In other words, having a family member who is an engineer was not a mandatory condition for the women's interest in engineering and decision to major in engineering. When applicable, engineer family members served as role models and were able to provide "insider" perspectives to the women as they navigated their decision making leading to the entry to the profession. This does not mean that women without an engineer in the family did not find themselves being encouraged, empowered, and supported or identify certain family members as role models in their journey to the profession. Rather, such familial influences were reported as manifested in shaping the

women's characters and dispositions such as having curiosity, embracing challenges and uncertainties, and learning from failures. All women spoke about learning such important characters and dispositions through interacting and observing their influential family members, regardless of whether such messages were intentional and clearly articulated or not by such family members. Here are some exemplary participant comments supporting this thematic finding:

> No one in my family has really been involved in engineering. Neither of my parents are engineers. I'm actually a first-generation college student, but my grandma did work at a chemical plant in [name of the city], [name of the state]. Knowing some of the work she did and the kind of work that she put into her career – I kind of always noticed that, growing up, how it was regarded as kind of rare, I guess, for a woman, especially for my grandma's time period, to work in that sort of field at a chemical plant. I went to the chemical plant a couple of times growing up, kind of saw what she did…. That was my first sort of exposure to any sort of engineering or STEM related field. [Quotes from K.C1]

> I am [originally] from [the country she immigrated from], and I grew up in a small country in a small town. It's very challenging for a woman to actually build up their career there. But my mom has a great impact on my life because since I was born, I saw my mom working. She never stopped working, and my grandma always supported my mom to work to get educated. All my aunts are working. [Quotes from U.A1]

> I wanted to be a doctor up until my junior senior year of high school. I was talking to my dad and I said, "I don't know if I want to do this." He said, "[name of the participant], you're really good with computers." And, I was. And, naturally, I just fell into it, and I chose Computer Engineering as my first major. [Quotes from U.B1]

The family member or members that the women reported as influential to their entry to engineering did not necessarily all hold an engineering degree or career. Rather, they tended to influence the women in the ways of "being who they are."

> My sister, [name], is one of the most influential people in my life, and she still influences me. We were pretty close in age, about five years apart. …. We're all pretty close which is amazing, and I love that. We were both clarinet players, and we both play volleyball, and so we would have nights where we played volleyball outside and until it was dark. So, I had a really strong connection with her. And she also did like AP classes in high school …. She's just someone that I look up to, and she has provided great advice, like me trying to be fun [being around] but also hardworking. [Quotes from K.L1]

This leads to the next point that we have observed in our findings: while all women have supportive families, intentional or critical development of gender consciousness did not necessarily all begin or be emphasized within the family environment. For some women participants, their parents have followed more traditional gender roles. For some women participants, certain parental and cultural circumstances made them recognize very early on the gendered expectations and consequences of "violating" such expectations. And for other women participants, their parents did not shy away from talking about gender and gender-based inequity

even when they were at a young age. Regardless, what was consistent across all families was the emphasis on the value of education, and the emphasis that the women can do anything they want to do and can be anything that they want to be. As one participant put it, "I am very much supported at home with my decisions as long as I stay in school."

> My mom has always had work and always provided income every single year, even though she's been a stay-at-home mom and do[es] that work at the same time. My dad is now the director of engineering at the company.... My mom did a lot of programming, especially when we were younger. She would do that in our little office section of the house. Both my parents got a degree in engineering. [Quotes from K.S1]

> In [the name of the country she immigrated from], women are not allowed to do many things, like going out alone; they got teased by that and I had encountered one of them. It is getting a lot better. There, people think that girls do not do science or math, they might be little dumb, but I wanted to say that this is completely a wrong thing. Anyone can do anything; you have to believe in yourself. [Quotes from U.A1]

Nevertheless, in one way or another, the women participants learned to embrace challenges. They also learned to take failures as part of a process *and* necessary elements for learning and growth. As one woman shared, "Now that's my instant reaction. When I fail at something, I think, 'What can I learn from this?'" They failed, knowing they would always have support and encouragement from their family.

> *B. Developing a sense of self in general and in relation to engineering through early encounters of empowerment, reaffirmation, and challenges from external educational and social forces.*

Alongside the familial influences, K-12 education and the broader sociocultural contexts in which the women have resided also played a role in the women's development of self-awareness. The women participants generally regarded their ability to perform well in math and science in K-12 education gave them a baseline indication that they could make engineering their college major. Associating one's performance in math and science subjects to "eligibility for entry" to engineering; this is reinforced by their schooling experiences. It is also reinforced by the dominant view and discourse on engineering *and* people close to the women such as family who have a more direct influence on the women's view self in relation to the engineering fields. The women's development in awareness of gender and other pieces of their social identity complicates such a seemingly mandatory prerequisite relationship between the two. For some women, while they were able to challenge some essentialization, like girls are not good at math, they did so by outperforming to prove they are "more than good enough." For some, they were able to question more of the fundamental societal gender inequity as manifested in their personal and educational life, allowing them to reject unequal, gendered expectations and treatments explicitly and implicitly. For instance, one woman participant shared that growing up, when she went car racing with her father, she found it absurd or problematic seeing some women would paint their cars pink and sparkle and ensure themselves act very "femininely." [C.L1]

I have always been good at science and math. So, then those are the biggest things you need for STEM and I like asking questions, figuring out how things work. [Quotes from U.E1]

After sixth grade, my family moved to [name of the town], [name of the state]. I was like, "Well, they don't know that I'm a smart girl, I got to prove that I'm the smart girl and I don't know how to do that." I remember, in a science class, by the second week, I had actually gotten something wrong, and I got a nine out of ten and I was like, "Dang it." I want it to be perfect for the rest of my life. [Quotes from K.S1]

I am [women of color]. We had guest speakers come to our class lot of the times, but I just remember constantly that the teachers and guest speakers would tell us, and encourage any minority to pursue STEM, and especially if we were female. I was told that we need people that have your perspective to come up with solutions, not just a set of majorities. So oftentimes people associate engineering with white males and predominantly that is what those have been in those roles. [Quotes from U.K1]

It is not uncommon that the women reported experiencing pressures of gender roles outside of the family. The women participants coped with frustration that resulted from such experiences differently, and not all coping mechanisms came without a price on the women's mental and physical health. Nevertheless, it seems that our women participants have found ways to mitigate such harms by relying on a network of family and friends, and at times, teachers and faculty. The women keep their focus on the "prize," the end goals. They also find joy and meaning in what they do in schools, extracurricular activities, and project teams. Occasionally the participants noted their project team which allowed us to observe such patterns even though this was not the focus of the first interview.

Nonetheless, it helps us to introduce the last theme observed in the first interview data, that is, being able to engage "*doing.*" Here, "*doing*" means being able to be hands-on to create something, to solve real and concrete problems, and see tangible products. We found the process of *"doing"* has brought the women joy in the process. This gives them a sense of purpose and accomplishment, and strengthens their passion for engineering. It also helps them to identify with the profession as part of who they are. Here are some example comments from our participants, illustrating this finding.

In childhood, I have always liked fixing things, building things, and doing things like that, working with my hands and having a project that I can complete and then it's done…. I'd rather do something that's practical, that I'm good at, and isn't as subjective in terms of judgment from peers and things like that. I've always felt like that has just been a part of who I am. I've never been afraid to try something new. [Quotes from K.A1]

I have basically enjoyed manufacturing things, so I can create something by my hand. So, machine shop is always my favorite spot to go and spend time. [Quotes from U.A1]

The women also reported a variety of extracurricular activities which they were "very good at," such as car racing, debate, choir, and other types of clubs and competition teams. Such

engagements, regardless of the end results and so-called performance levels, have provided the opportunity for these women to learn more, build their self-efficacy, and connect with their peers. These activities tended to be challenging, require a lot of commitment, and individual "capacity." Thus, when complete the feeling of success contributed to the women forming positive identities. As one participant noted, "I'm actually happy that I had to work really hard for it, because I know it was all me." Equally beneficial are those less intensive and/or team-based extracurricular activities, where the women developed critical soft skills, formed friendship and community, learned group/team dynamics, and most importantly gained earlier glimpses into the impact of leadership. All these have informed and shaped the women's continuous journeying into engineering and project teams.

Discussion and Implications

Limited literature has focused on the "positive," that is, the personal experiences and institutional factors contributing to the success of undergraduate engineering women. Our research attends to address such a gap. As the research is ongoing, the current paper reports the findings observed from the first interviews. Similar to what has been noted in the literature, we found family plays an important role in the women's character and disposition development, identity formation, and pathways to engineering. Particularly, having female role models is instrumental in women's development in relation to the field of engineering. Furthermore, K-12 education experiences are "playgrounds" for the women to explore personal interests and strengths (and weaknesses), gain confidence and reaffirmation even when at times facing obstacles and failures, and find joys in being hands-on and producing tangible outcomes [18, 20, 21, 22]. All of these contribute to molding the women's views, attitudes, and competencies potentially key to succeeding in engineering, even under unwelcoming and challenging circumstances.

From the very beginning, it is our intention and commitment to recruit women undergraduates of diverse backgrounds (i.e., race, socioeconomic status, ability, etc.). We understood the importance of intersected identities in shaping one's experiences, views, and actions. Intersectionality, as created and defined by Kimberle Crenshaw and defined in Merriam-Webster, is "the complex, cumulative way in which the effects of multiple forms of discrimination (such as racism, sexism, and classism) combine, overlap, or intersect especially in the experiences of marginalized individuals or groups" [35]. As of now, we have focused on recruiting participants who identify as women and the participant pool is primarily white. While reflecting on the general demographics of women in engineering education, we continue to seek possible recruitment strategies to increase participant diversity. Furthermore, we have noted codes and patterns observed that appear to be unique to the very small sample of women of color at this stage. Also, since the focus was on women who are thriving, it is unclear if the women who left project teams did so because of gender, race, class bias, or a combination.

Lastly, as noted above, this is only a portion of the data that the research project is set to collect. We have begun the second and third interviews. As of May, 2022, we have completed four first interviews from the Northeast University, six first interviews and four second interviews from the Midwest University, and seven first interviews from the Southwest university. Our progress has been delayed due to COVID-19 and variable based on policies for on campus activities at each institution as a result of the pandemic. Once we complete these 90 individual interviews, we

plan to invite women from two conferences to participate in multi-institution focus groups in order to see if our findings relate to the entire nation. Conferences with project team competitions are still routinely cancelled due to COVID-19, thus we may alter our protocol for creating these nationwide focus groups. The combination of interviewing women from the three institutions in our study as well as women from across the nation in focus groups will provide a broad insight into the personal factors that allow women to thrive. In addition to these personal factors, it is important to look at the role of institutional policy and culture play in women's ability to thrive.

Conclusions

Though previous studies explored why women do not go into engineering and institutions implemented efforts to increase the number of women in engineering, the number of women remains stagnant, at around 20%. We learned from our data that women who are thriving in engineering come from supportive families who let them pursue their passions, they think of themselves as good at math and science, and they like hands-on activities. This dedication and perseverance allow women to stick with the project teams. If administrators follow in these women's footsteps and create policies to improve the work environment within project teams, more women would likely remain on the teams and in the engineering major. With more women in the field, there will be a broader range of perspectives and ideas which is vital in a field based on innovation. The women will push other engineers to think critically and consider perspectives they hadn't before. This will improve the quality of engineers' work and overall improve the field with the implementation of new, creative solutions. The journeys of these women provide a framework for how other women can be successful in engineering and how institutions can create a more diverse and inclusive engineering college. In creating a more diverse field, we will include a broader range of perspectives and ideas in decision making which will improve the quality of work and allow engineers to solve problems they previously could not.

Acknowledgements

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