First-Year Women's Interpretations of Self-Efficacy After an Ecological Belonging Intervention

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Introduction

For decades, engineering education research has documented the persistent underrepresentation of women in engineering [1], [2]. Numerous findings have shown that these issues are not a result of aptitude or preparation for foundational skills such as mathematics [3]. As such, researchers have focused more on examining differences in women's attitudinal and psychological variables than their men peers in areas of self-concept, confidence in their engineering skills and ability to succeed, belonging, and career goals, among other factors [4], [5], [6]. These studies have created a descriptive understanding of gender differences and have provided numerous suggestions for support for women to navigate an often "chilly climate" in engineering [7]. Recent research points to the double threat of negative stereotypes about women in STEM and being underrepresented presents to academic and career experiences Numerous findings have shown that these issues are not a result of aptitude or preparation for [8]. There are examples of successful efforts to support women that provide counter spaces to this chilly climate [9], [10]. However, fewer studies have examined how to address the root causes of these differences due to engineering environments that can negatively impact women's experiences and fail to provide the same opportunities for women to develop their beliefs in their futures in engineering [11], [12].

Some of the strongest signals of who can be an engineer are conveyed within the classroom environment through interactions with instructors and peers [13], [14], [15]. In particular, students' experiences in the first two years in "gateway" courses most strongly influence student academic outcomes [16], particularly for women and shape decisions to stay in engineering majors or to leave [17], [18], [19]. As a result, these classroom environments offer a prime opportunity for interventions to support women more equitably in engineering by addressing the signals about who belongs in engineering.

Ecological Belonging Intervention Project

This work-in-progress (WIP) paper builds on a larger study focused on understanding a one-time ~40-minute ecological belonging intervention across multiple engineering courses and institutions (NSF DUE 2111114/2111513). The ecological intervention occurs **within the classroom** (and is facilitated by the instructor) and is hypothesized to change classroom-level social norms [20]. The intervention conveys a core message: the typical college struggle is normal and surmountable. The intervention consists of four main parts: 1) an introduction of the intervention message through faculty sharing a story of their struggle; 2) individual reflection about previous struggle and the process of navigating it; 3) sharing contextualized, composite stories from students who previously took the course about common struggles; and 4) small group discussion and share out (for more details on the intervention refer to [21]). The types of struggle may vary by student but include learning how to study, finding friends, working in engineering teams, and feeling overwhelmed by the course content, etc., which often positions students in a space in which they question if they belong. This belonging uncertainty, coupled with stereotype threat, can result in a negative disparate impact on marginalized groups in

engineering. As such, this work focuses on typical adversity faced by college students, not the impacts of sexism, racism, homophobia, or other forms of bias in engineering education.

The impacts of this intervention on both students and faculty are being studied through quantitative instruments, classroom observations, and longitudinal interviews with 71 students stratified by intervention group, gender identity, and racial/ethnic identities. Results from our quantitative analyses indicate promising trends in the intervention for addressing academic equity gaps (i.e., differences in student academic outcomes due to systemic issues in engineering and not individual student characteristics) for Black, Latino/a/x, and Indigenous students in buffering against a belonging decline over the semester and on lower individual assignment scores in an introductory programming course [22]. Our preliminary analyses also indicate that women who receive the intervention may be more likely to persist in engineering than women who did not receive the intervention. We hypothesize that the intervention may be shaping how women conceptualize struggle and their abilities to do engineering work, e.g., their self-efficacy. As such, this WIP focuses on interviews with four women—one who received the intervention and stayed in engineering, one who received the intervention and left engineering, one who did not receive the intervention and stayed in engineering, and one who did not receive the intervention and left engineering—and their descriptions of their self-efficacy for being successful in their engineering major.

Theoretical Framework

Self-efficacy is the belief in one's capacity to execute behaviors necessary to produce specific performance attainments (e.g., engineering degree attainment). Self-efficacy has been related to women's plans to persist in engineering. Women who have higher self-efficacy, especially Black, Latina/x, and Indigenous women, are more likely to persist in engineering careers [23]. Conversely, research has demonstrated that women who have lower self-efficacy are more likely to drop out of engineering despite having similar grades as the women who stay [24]. Additionally, women who stay in engineering often have lower self-efficacy than men in the same classes, which can influence how challenges are interpreted throughout engineering [25].

Bandura has developed four sources where self-efficacy beliefs can be developed: mastery experiences, vicarious experiences, social persuasions, and physiological states where mastery experiences contribute the most to a student's beliefs [26]. Specifically, many factors can impact a student's self-efficacy beliefs within engineering. These factors include understanding or learning of the material; drive or motivation toward success; teaming issues; computing abilities; the availability of help and ability to access it; issues surrounding doing assignments; student problem-solving abilities; enjoyment, interest, and satisfaction associated with the course and its material; and grades earned in the course. Drive and motivation, understanding of the material, and computing abilities were found to be the most influential factors that impact their confidence in succeeding in an engineering course [27]. Self-efficacy has been a focus of many research studies, particularly those on gender, because it has been found to be an important link between student experiences and confidence in key tasks associated with becoming an engineer [28].

Research Purpose and Questions

This WIP investigates the self-efficacy descriptions of four ciswomen from the larger ecological belonging intervention research study. These women were selected for this analysis in a 2x2 sampling strategy of belonging intervention (control versus treatment) and retention one-year post-treatment (stayed or left). This study is an initial investigation of the different and similar ways in which these women discuss how they perceive their abilities in relation to their peers in engineering to understand better how women interpret messages and form self-conceptions in engineering for future interventions to support retention. In this paper, we address the questions:

> **RQ1:** How do women in engineering who have and have not experienced an ecological belonging intervention describe their beliefs about their abilities to succeed in their engineering courses?
> **RQ2:** How are these descriptions related to women who stayed in or left engineering?

Methods

The data for this study come from interviews at a large, public, research-intensive Midwest institution after an ecological belonging intervention in a required first-year engineering introductory programming course in Spring 2022 and 2023. In Spring 2022, 307 students were in the "business as usual" sections and 334 students in the experimental sections. The response options provided a multi-select option, so the percentages listed in Table 1 may sum to more than 100%.

Table 1. Demographic data for the broader study.

	% in Treatment	% in "Business as Usual"
Race/Ethnicity		
African American or Black	1.7	1.9
Latino/a/x	5.5	8.1
American Indian or Alaska Native	0.8	0.5
Native Hawaiian or Pacific Islander	0.5	0.2
White or Asian	86.2	84.0
Preferred not to respond	29.1	2.3
Gender		
Men	72.4	66.0
Women	25.8	31.0
Non-binary	0.6	0.8
Preferred not to respond	1.2	2.2

We asked students to indicate interest in participating in longitudinal interviews through a pre-screening survey. We used the survey to stratify a sample for interviews by treatment condition, gender, and race/ethnicity. A total of 71 students completed at least the first interview during the following semester (i.e., Fall 2022 or Fall 2023), and 35.3% of this group were women. For this WIP study, we focus on four women (refer to Table 1) to identify starting themes for how the

ecological belonging intervention may shape women's conceptualizations of self-efficacy and retention.

Table 2. Study participants in this WIP.

Participant Pseudonym	Belonging Intervention	Retention One Year Post
Maria	Control	Left
Tina	Control	Stayed
Jasmine	Treatment	Left
Emilia	Treatment	Stayed

The interview was conducted by various members of the research team. Where possible, we attempted to pair interviewers by gender and/or race/ethnicity. The semi-structured interview lasted approximately one hour and focused on students' pathways into engineering; experiences in college; self-identified gender, racial/ethnic, and sexual orientation identities and how those shaped their experiences in engineering; perception of themselves as engineers; and sense of belonging. The data were audio recorded and transcribed verbatim.

Analysis

Two initial coding approaches were employed by the first author to analyze the interviews. In vivo coding was utilized to capture the participants' expressions in their own words, aiming to grasp the essence of their statements. Inductive descriptive coding was applied to rephrase participant statements into more general terms, generating codes in tandem with the data [29]. The first-pass coding was created with comments on interview transcriptions and later transferred to an Excel sheet with the original quote, in vivo code, and descriptive code for further examination. Following each coding session, reflections, emotions, impressions, and interpretations were recorded in a memo document to note emerging trends. After the preliminary coding, a second-pass axial coding was conducted on the Excel sheet to identify common themes related to the control/treatment group and the decision to stay/leave. These emergent codes were discussed with the second author to refine the claims made from the data and for coding consensus.

The authors of this paper have varied experiences with engineering and as members of the groups we interviewed. The research team of faculty, postdoctoral scholars, graduate students, and undergraduate students included researchers from higher education and engineering education. Three of the authors have experiences as women in engineering education. One faculty author has been engaged with the design and teaching of the course of study. As Latinx and White scholars, these identities have influenced the teams' engagement with research participants. The first and second authors conducted the analysis and met regularly to discuss the findings and interpretations as well as the influence of our positionality in this work.

Emerging Results

After analyzing the interview data, three prominent themes emerged. First, in the control group, students exhibited self-awareness with respect to their lower confidence in their abilities than their peers. The second theme that emerged was that students who were in the treatment sections consistently described that their engineering skills were above average compared to their peers despite the feeling they were struggling overall. Conversely, the students in the control group only talked about how they felt average or below average compared to their peers, failing to mention areas where they excelled. Lastly, it was clear which interviewees left engineering from the discussions of their negative experiences within engineering. The participants who left the major mentioned in their interview how they were struggling to manage their coursework with their personal well-being. Overall, the results indicate potential positive buffering effects for how women interpret typical struggles associated with learning challenging content and may boost self-efficacy beliefs. However, the intervention is not a fix for engineering cultural norms that can create spaces that undermine well-being and ultimately push students out of engineering.

Awareness of Lower Confidence

The two women who were in the control sections described lower confidence in their engineering skills than their peers, and they were aware that they had a lower confidence in their abilities. This observation is noteworthy as it explores a level of self-awareness that students may not typically possess. The realization that they predetermine an outcome or undermine their own possible successes without specific external cues aligns with how self-efficacy beliefs can be shared by simple stereotypes and under-representation in engineering. These interviews also emphasized how these internal beliefs can shape students' engagement and outcomes. One participant was very direct with this understanding, Maria (left engineering, control group) said,

> I had say for my other classes, and I feel like I'm already going to write myself lower than it should be, but I feel like otherwise from my other classes, I'd say my skillset in the classes are maybe a seven, I dunno, six or seven [out of a possible ten]. But like I said, I feel like one of the things that I've always struggled with, especially in these big classes, is just having the confidence in my own abilities with them.

Another participant, Tina, shared additional details on why she had lower confidence in her engineering abilities than her peers, "I definitely think it's probably from my own insecurities, but I can also feel like sometimes I'll ask something, and maybe someone might ignore me... Like I ask something, and they'll just block me out, or just ignore me."

Differences in Discussing Skills by Intervention Groups

The interviews revealed a difference in discussing their skill set between the treatment and control groups. Overall, all women discussed their skills as average or comparable to their peers or below average in comparison to their peers. The difference occurred in the explanations of these answers. Women in the treatment group provided additional details on the skills they felt they were best at and how they were similar to their men peers in their courses. In contrast, the

women in the control group only focused on where they were less felt they were less proficient or confident than their men peers. For example, one participant, Emilia, who was in the treatment group and stayed in engineering, thought she had an average academically but exceeded socially in the major.

> I know this is a very academic school, so I wouldn't put myself up as one of the top academic students here. I feel like, overall, I do fall kind of average. I'm not failing my classes. I have a 3.4 right now, and so I'm barely the cutoff of the dean's list, but I'm not doing bad, but I'm not doing oh 4.0 amazing. All A and everything. And so I feel like overall my skillset, I feel like I am a bit more, how do you say it? Like social engineers especially. I was already talking about the stigma. A few of my friends, they are smarter than me. I know in assignments they'll be finishing super fast and everything and I am proud of them for that. But just overall, I know socially I'm more socially aware and able to adapt to things better.

Another student in the treatment group, Jasmine, also said she was struggling academically compared to her peers. However, in addition to her academic struggle, she also talked about all the technical skills that she did possess that her peers did not. She was confident in her technical/hands-on skills:

> I've been struggling as a student, not going to lie. I think I have the potential to be a very good student, and I just have issues getting there... Yes. I also would say I have a lot of different experiences than my peers. A lot of the people I've met, they either know nothing about engineering or they have done engineering before, but it's more personal projects they've done or clubs they've been into where I have a very technical skill set. I don't mean to brag, but honestly, I can build you anything you want… I could do that to where my peers have more of this theoretical knowledge about engineering, or they can code or things like that, their skill sets are pretty different because, honestly, most 19-year-olds could not just build you about anything you wanted. It's a very different skill set that I have.

This divergence in responses points to the potential positive impact of the intervention on shaping a positive self-perception despite typical adversity and warrants further study. The intervention group exhibited a tendency to emphasize strengths and achievements, showcasing a shift in mindset towards a more constructive self-evaluation. This aligns with previous research emphasizing the importance of drive, motivation, and computing abilities in enhancing students' self-efficacy [27]. This finding connects back to literature on women's self-efficacy in engineering, suggesting that interventions, like the ecological belonging intervention, play a role in instilling drive and motivation. By normalizing struggle and emphasizing perseverance, students may become more inclined to recognize and share their strengths.

Contrastingly, those in the control group overlooked their areas of expertise when comparing their skill sets to their peers, despite having similar backgrounds. They simply stated that they were either average or less than average compared to their classmates without stating something they were confident in. This inclination towards the negative suggests a potential barrier to

cultivating a positive self-perception within the control group. For example, “Interviewer: And how would you compare your skillset to the men engineering peers of your classes? Maria: I would say it’s less... Not significantly, but I do feel like it’s behind them”

Engineering Impact on Well-Being and Retention

Finally, for women who left engineering, larger factors related to the culture of engineering and negative impacts on stress and well-being were discussed. Engineering culture has been characterized as a “meritocracy of difficulty” [30] that valorizes “suffering and shared hardship” [31] and academic excellence above all else [32]. While the intervention does seem to provide some support for how students interpret typical struggle, some women described a struggle that pushed them out of engineering. Despite being enthusiastic about engineering, these women left because the cultural norms of engineering they described were negatively impacting their well-being. One participant, Jasmine, was overwhelmed after the first semester and mentioned being burnt out. She focused on managing their disabilities and was unable to attend to all the needed efforts for their well-being. This impacted their grades and their confidence going into their second semester.

> I also struggle with burnout. My first semester, I did fantastic. I was all about the self-regulation until I burnt myself out, and then I could not do any more of my work and just the motivation was gone, the mental health was not there and just managing that balance can be a little difficult by myself, I found out. So, once I have that managed then I can be a good student, but it’s finding that balance in my personal life that affects my academic life.

Another student who left engineering, Maria, also struggled to find a balance between engineering coursework and their personal well-being. This student is a student-athlete. She found it difficult to juggle her classes and social life.

> So I feel like with engineering specifically, even if I wasn’t a swimmer, the class schedule is very demanding. And engineering, I feel like, is also, there’s a sense that it’s cutthroat, especially in first-year engineering. So, there’s a sense that it’s competitive and there’s a sense that we’re always doing homework and that our class schedule’s busy. So, I could see how that takes a hit on you socially. So yeah, I feel like it is kind of difficult to make friends, but I think that’s also me a little bit.

This result aligns with existing literature emphasizing the impact of self-efficacy on students’ intentions to persist in engineering [33] as well as the impact of engineering stress culture on student’s well-being [34]. Burnout, even with the belonging intervention, remains a formidable challenge influencing decisions to switch out of engineering. These experiences may be more frequent for students with additional layers of time commitments via care responsibilities, extracurricular commitments, and efforts to financially support their studies. The experience of being a woman and Black, Latino/a/x/é, Indigenous, international, socioeconomically disadvantaged, and LGBTQ+ can also shape how these students experience an engineering culture that was not created for and often does not support individuals from these communities

[35], [36]. The struggles faced by these students underscore the need for comprehensive support beyond interventions, encompassing mental health considerations and balancing academic and extracurricular commitments [34].

Future Work

Moving forward, there is an interest in furthering the analysis of this study. Given that the current state is a WIP, it is essential to acknowledge that only a limited subset of interviews has undergone analysis despite the availability of a larger sample size. The intention is to delve deeper into the exploration of whether the identified themes persist as more interviews are examined.

In addition to the extended analysis, a commitment is in place to sustain the implementation of the belonging intervention in first-year engineering classes. This continuous effort aims not only to validate the persistence of observed patterns but also to gauge the long-term effectiveness of the intervention in influencing students' perceptions, self-efficacy, and overall experiences within the engineering curriculum.

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