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Changing Classroom Ecology to Support Continued Engineering Enrollment

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Abstract: Engineering requires more bachelor's degree graduates to meet the growing demand for engineering skills globally. One way to address this demand is increasing student degree completion, which is lower than higher education in general. In particular, Black, Latino/a/x, and Indigenous (BLI) students are less likely to complete an engineering degree than their peers. BLI students experience a host of unwelcoming behaviors in engineering environments that contribute to departure without their intended degree. Improving environments to support belonging may offer one solution. Through an ecological belonging intervention, we seek to improve continued enrollment and increase belonging. Quasi-experimental methods were used in a second-semester engineering programming course. Surveys collected before and after an intervention combined with institutional data were used to test the moderation effects of the intervention on continued enrollment in engineering during the semester following the intervention. BLI students who were enrolled in intervention treatment sections were more likely to be enrolled in engineering the following fall. The intervention treatment increased belonging such that control section participants were less likely to continue to be enrolled in engineering. While research to assess the efficacy and mechanisms of the intervention is ongoing, the intervention offers promising results to address attrition, particularly for BLI students.

Keywords: engineer; belonging; programming; Black; Latinx; Indigenous; persistence

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1. Introduction

STEM fields have long sought to improve the retention of students to degree completion [1]. In engineering, broadening participation has been particularly important for meeting workforce needs and broadening who engages in engineering from marginalized groups (i.e., women and Black, Latino/a/x, and Indigenous students [BLI]) [1]. Engineering environments are dominated by white and Asian men [2], and as a result, some students feel a lack of belonging in engineering classrooms. BLI students describe engineering environments as isolating and unwelcoming [3–7]. Engineering climate has also been described as a "chilly" environment for marginalized students [8,9]. Together, these histories of exclusion negatively shape those who pursue engineering pathways and who stay in engineering.

Underrepresentation and higher-than-average early departure rates for BLI students continue to be problematic despite decades of research attention. Overall, white students tend to persist in STEM majors at higher rates than their peers [10–12]. Similarly, national research has demonstrated gaps in persistence for BLI groups [13–15]. Black and Latina/o/x students in STEM majors are more likely to switch from a STEM major to a non-STEM

major or leave higher education without a degree than their white peers in engineering and their Black and Latina/o/x peers in non-STEM majors [16,17].

As a result, BLI students remain underrepresented in engineering bachelor's degree earners compared to the U.S. population [18]. In predominately white institutions (PWIs), BLI students experience unwelcoming classroom environments that include stereotypes, microaggressions, intersecting oppression, exclusion and isolation, and a lack of similar mentors, faculty, and peers in engineering [7,17,19–22]. The additional stress and coping required burdens BLI students beyond the rigors and challenges typical of college education [23–26]. The result for many BLI students is an environment in which feelings of not belonging contribute to departure considerations [17,19,27,28].

BLI students experience marginalization in engineering environments through isolation, invisibility, impostor syndrome, discrimination, and microaggressions [7,17,19,20,22,27–34]. While experiences may be similar, groups within the aggregate BLI group experience distinct oppressions, exclusions, and cultural barriers to success in engineering. For example, Black students' skills and belonging may be questioned with suggestions that they are unique or have otherwise gained an unfair advantage [34] with the conflicting message that they will not succeed [17,35]. Cultural expectations of familiarity, connection, and support may leave Latinx students feeling disconnected from faculty and peers in science and engineering [36]. Indigenous students face a unique discrepancy between Indigenous and scientific epistemologies that requires the management of cultural and spiritual burdens [37]. Despite the body of evidence that demonstrates unequal experiences for BLI students, engineering classrooms often engage in "colorblind" approaches, which exacerbate racial/ethnic inequalities under the guise of fairness and meritocracy [38–43]. Often, BLI students are expected to represent their race and ethnicity in a space that attempts to imply that race and ethnicity do not matter [32]. The strategies BLI students undertake require additional effort to cope with stereotypes adding emotional strain to an already demanding college [20,44] that ultimately threatens BLI student success [20,21,37].

A strong sense of belonging plays a critical role in retention and persistence in college students [4,5,17,30,45,46]. Belonging represents a student's sense of being connected with their peers and instructors within a classroom environment [1,2]. Belonging includes feelings of being accepted and included by important others, which has been identified as a basic human need, and as a result, belonging is an important aspect that shapes student experiences [3]. Students may not even be aware of the importance of belonging in introductory courses [47]. Sense of belonging links to academic outcomes such as persistence, adjustment, and achievement [4,5,17,46–50]. Belonging serves a primary function in connecting peers and academic institutions [51]. A tenuous sense of belonging or belonging uncertainty hinders student engagement with learning [52]. Experiences of being marginalized reduce the sense of belonging [53], and racial and gender disparities in engineering [54,55] often reflect the lack of belonging felt by many engineering students. These experiences have cascading effects that can further negatively impact connections and interactions with peers [4,6,17,56], faculty, and mentors [17,57,58]. In all, these experiences are systematic and cultivate environments that threaten belonging, which are not the same challenges faced by White and Asian peers (i.e., majority peers) [17,43,53].

Identity-based affinity groups can support community and belonging to combat race and gender stereotypes prevalent in STEM environments [30]. Students who engaged with a range of communities beyond engineering found support to overcome identity-based obstacles [59,60]. However, these groups do not address the classroom environments in which students learn. Faculty play an essential role in promoting belonging by integrating culturally responsive curriculum and allowing students to bring social identities into coursework while fostering a welcoming environment [19,61,62].

Significant research has been dedicated to documenting students' experiences of (or lack thereof) belonging; however, less research has emphasized increasing belonging as an intervention to combat high attrition rates in BLI students. Some short interventions positively improve students' sense of belonging [63]. For example, academic performance

improved for Black students following a 45 min social-belonging intervention [53] with positive effects years later [64]. The successful intervention asked students to simply read stories of previous students who overcame adversity, thereby normalizing struggle and showing that students can overcome adversity. However, belonging intervention efficacy results remain mixed [65,66], partially due to the heterogeneity of the classroom experience. In an introductory calculus-based physics course required for engineers, our ecological belonging intervention eliminated gender achievement gaps while boosting overall attendance [52]. Similarly, BLI students who participated in the intervention maintained belonging while participants in the control decreased in belonging scores from pre- to post-test [67]. In addition, BLI students in the intervention condition had significantly higher individual MATLAB grades at the end of the semester than control participants [67].

This study examines the positive effects of a belonging intervention delivered in a first-year engineering course for BLI students at a PWI on continued enrollment and the effect of belonging on continued enrollment of engineering students more broadly. Through the intervention, students learn that typical struggle in a university context is normal (e.g., experienced by the majority of students, while the specific struggle may differ) and with time and effort surmountable. When students recognize that others experience academic struggles, they can better recognize that struggle does not set them apart. Additionally, framing struggle as a surmountable experience with time and effort normalizes and emphasizes opportunities within students' loci of control to seek support and successfully navigate engineering pathways. This reframing of struggle (re)shapes the ecology of the classroom to open dialogue around struggle and support persistence through struggle as something that indicates normalcy rather than a signal that they do not belong. Importantly, this intervention is implemented in a course with demonstrable and sustained equity gaps in course grades for BLI students, which we hypothesize is driven in large part due to environments that do not support belonging.

The Intervention

A prior social belonging intervention demonstrated the utility of teaching students that typical adversity in college is normal and surmountable with effort [53]. In psychology lab settings, previous research demonstrated the individual effects of social belonging [53]. Our project adapted prior social-belonging interventions [8,53,68] by tailoring the intervention messages to course-specific challenges experienced by previous students to address the ecology of the course as well as individual perceptions of challenges [69]. Based on prior social belonging interventions [70], the basic ecological belonging intervention, developed by Binning et al. [52], supports the message that typical adversity is normal and surmountable by creating opportunities to engage in discussions of struggle within the course environment. Students learn about adversity, struggle, and achievement through personal narratives to build a classroom ecology that supports student development and recognition that they are not the only ones struggling, thereby shifting the classroom dynamics to endorse challenges as normal and surmountable with time and effort.

Engineering and education experts on the team contextualized the basic ecological belonging intervention [52] to be implemented in the introductory programming course (refer to [69] for contextualization details). The ecological belonging intervention includes instructor narratives of struggle combined with individual student narratives of struggle developed from focus groups with students who completed the targeted course previously and discussion in small groups and with the entire class. As such, the adapted intervention shifts classroom norms as well as student perceptions of adversity and struggles within a specific classroom.

The intervention course for this project was an introductory programming course required for all engineering students typically completed during the first year in the second semester at a large Midwestern, research-intensive university in the United States. Analysis of institutional grade data revealed that in this course a significant equity gap of a historical average of 0.44 points on a 4.0 grade point average exists for BLI student course grades.

The equity gap and the persistence of the gap over four years of data lead to our choice to target this course for intervention.

The instructor of the course delivers the intervention as a normal part of the course material within a single course (~45 min). This intervention occurs in the first week of classes to support students' interpretations of struggle before it occurs. The intervention establishes a classroom norm that typical struggle is a normal and surmountable experience with appropriate time and effort through five activities. First, instructors describe challenges students may be navigating such as transition into college, time management, course material, and workload. Next students write about one current struggle and are asked to consider how it might be addressed and overcome in the future. The instructor then presents a collection of stories from past students about overcoming struggles in the course. The stories reflect student experiences expressed in focus groups [69] and convey the narrative of students facing challenges as normal and surmountable experiences, the need for effort to overcome adversity, and the resolution of the challenge. After reading the stories, students engage in small group discussions with 3 to 5 peers during class. Discussion prompts allow participants to recognize struggle as surmountable by hearing their group's experiences and identifying commonalities [71]. By recognizing typical struggle as a normal and surmountable part of college education, students can better see how struggle does not set them apart or serve as a signal that they do not belong in engineering. Additionally, open discussion of struggle through the intervention changes the ecology of the classroom to support students through struggle. Additional details on the intervention can be found elsewhere [69,71].

2. Materials and Methods

2.1. Procedures

Seven volunteer instructors were assigned to serve as treatment or control instructors. Four instructors were trained to lead the intervention as an integrated part of their class. Student participants were not aware of the activity as an experimental intervention but rather an integrated part of the course. The other three instructors were used as control classes doing "business-as-usual".

As part of a larger project investigating an intervention to improve the sense of belonging and self-efficacy of students in an introductory programming course, participants completed a survey about their attitudes and identities during the first week of classes (pre-survey) and a second survey 12–14 weeks in the course after intervention delivery (post-survey) via Qualtrics. Additional information was collected from institutional records (described in Measures). All procedures were approved by the Institutional Review Boards of the first and second authors.

2.2. Participants

Approximately 1456 students were enrolled in the course in the Spring 2023 semester with 1185 students responding to sufficient items to be included in the sample. Participants were removed from the survey if they did not complete 90% of the survey items. Gender identity, race/ethnicity, sexual identity, disability, and international student self-identified demographics are reported in Table 1. For gender, transgender individuals are included in this sample as their selected gender. The sample well represents the university and geographic region.

Table 1. Sample Demographics by Intervention Status.

	Intervention Status	
Demographic Groups	**Control**	**Treatment**
Asian	149	154
White	439	495

Table 1. *Cont.*

	Intervention Status	
Demographic Groups	**Control**	**Treatment**
BLI	107	91
Black	14	12
Latinx	55	54
Indigenous	0	2
More than one	38	23
Gender		
Men	252	255
Women	133	135
Non-Binary	14	12
International Students	79	100

2.3. Measures

Continued enrollment in engineering courses in the fall semester following the programming course is the outcome variable ($n_{\text{Not Enrolled}}$ = 68, n_{Enrolled} = 1388). Enrollment data were collected from institutional records after the drop date for the fall semester of 2023. The moderator variable used in the analyses presented is the intervention: treatment (n = 767) or control (n = 689). The intervention variable was made based on the section of the course the student was registered for in Spring 2023.

The independent variables used as predictors in the moderation analyses are BLI identity and belonging scores. The BLI group includes all participants who selected Black or African American, Latino/a/x, Native American, or Native Alaskan, and participants who selected one of these and any other option from an item asking for race/ethnicity identity (n = 198). All other participants are included in the white and Asian groups (n = 1025). We acknowledge that these simplifications do obscure the unique experiences of BLI groups. Further, combining white and Asian masks issues Asian students face in engineering such as model minority biases and microaggressions [72,73]. However, we find these groups useful in detecting general patterns within our data for further exploration.

Belonging was measured with four items with the mean of the items providing the belonging score. Participants rated items as Strongly disagree (1), Disagree (2), Agree (3), and Strongly Agree (4). The survey instructed participants to *think about how they felt about their engineering course* with the following items: *I feel like I belong*; *I feel like an outsider*; *I feel like I can be myself*; *I feel accepted for who I am*. The belonging score demonstrated acceptable central tendency and normality statistics (M = 3.19, SD = 0.55, skewness = −0.44, and kurtosis = 1.25) and acceptable reliability (Cronbach's α = 0.69). BLI group is coded to BLI (1) or white and Asian (0). Continued enrollment in engineering is coded to be enrolled the following fall (1) or not enrolled (0). Intervention is coded to treatment (1) and control (0). The belonging variable is the mean of the belonging items.

2.4. Analysis

Descriptive statistics including means, standard deviations, kurtosis, and skewness were calculated using SPSS. Analysis of variance was used to determine if the treatment and control groups were equivalent in BLI representation. A one-way independent samples t-test was used to test for differences in belonging at the pre-test between the treatment and control groups. Linear regression analyses were used to demonstrate the main effects of the BLI group and belonging on the following fall enrollment. The main analyses used a basic moderation analysis with Model 1 in PROCESS [74]. Moderation analysis identifies if a moderator variable changes the relationship between a predictor and outcome variable. As such, the moderator changes the outcome variable. In this project, we seek to identify if

participation in the treatment changed the relationship between (1) the BLI group (Figure 1) and (2) belonging (Figure 2) with continued enrollment in engineering.

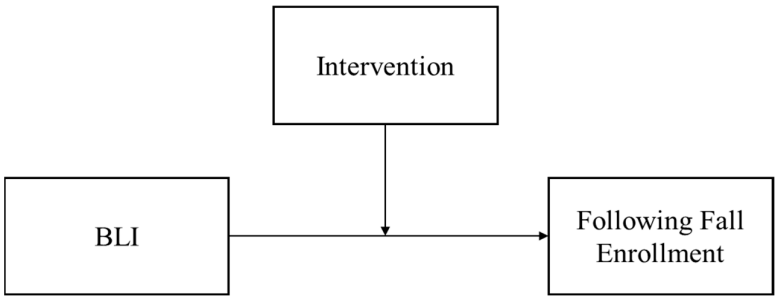

Figure 1. Proposed moderation relationship between Black, Latinx, and Indigenous status and continued enrollment in engineering by the intervention.

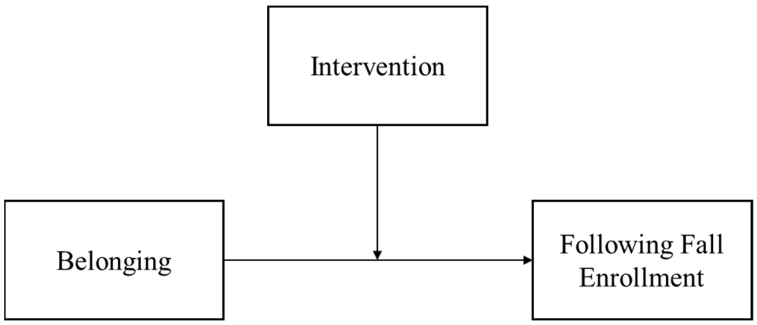

Figure 2. Proposed moderation relationship between belonging scores and continued enrollment in engineering by the intervention.

3. Results

The treatment and control groups were not significantly different in BLI representation (1, 157) = 1.06, $p = 0.305$). Students in the BLI group who did not receive the intervention treatment were significantly less likely to be enrolled in engineering the following fall ($\beta = -1.20$, $z = -3.09$, $p = 0.002$). The moderation analysis demonstrates the interaction between intervention and the BLI group, leading to increased continued enrollment (Table 2). The intervention significantly interacted with BLI groups to influence enrollment the following fall such that BLI students in the treatment group were more likely to continue enrollment, and those in the control group were significantly less likely to continue enrollment in engineering (Figure 3).

Table 2. Moderation of BLI Student Continued Enrollment by Intervention.

Predictor	β	S.E.	*z*	*p*	95% CI [LB, UB]
BLI	−1.20	0.39	−3.09	0.002	[−1.97, −0.44]
Intervention	−0.38	0.31	−1.24	0.215	[−0.99, 0.22]
BLI x Intervention	2.81	1.06	2.57	0.010	[0.67, 4.96]
BLI x Control	−1.20	0.39	−3.09	0.002	[−1.97, −0.44]
BLI x Treatment	1.61	1.02	1.57	0.116	[−0.40, 3.62]

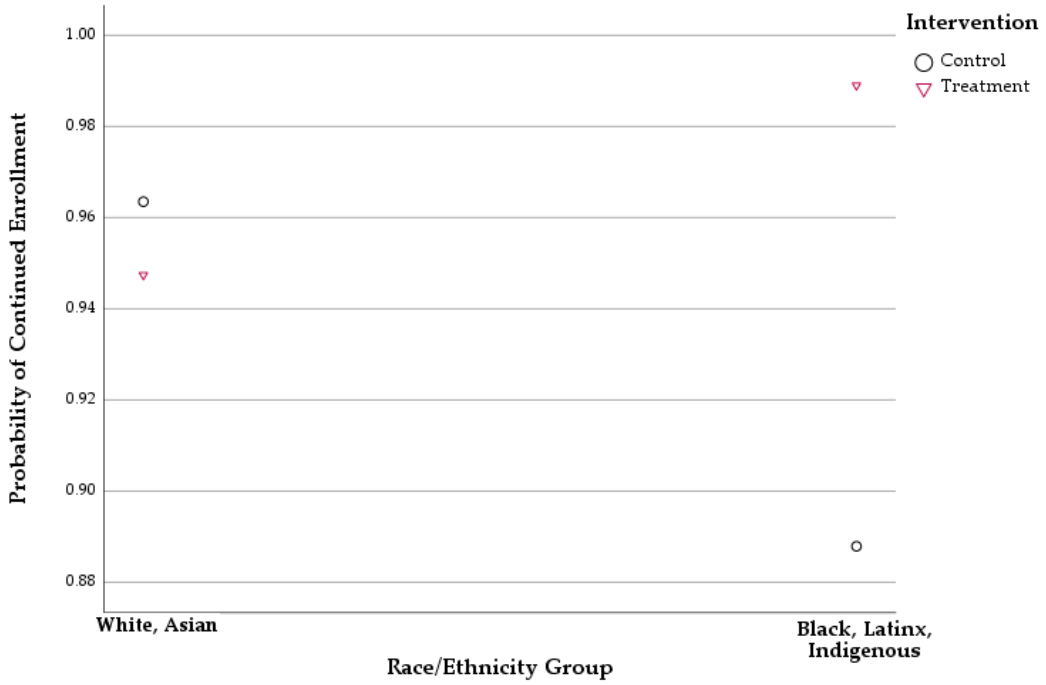

Figure 3. Probability of continued enrollment by race/ethnicity group by intervention group.

Pre-test belonging for control (M = 3.10) and treatment (M = 3.13) groups did not significantly differ in belonging in the pre-survey (F(583) = 0.27, p = 0.602). Post-test belonging for control (M = 3.18) and treatment (M = 3.22) groups were not significantly different (F(1681) = 0.07, p = 0.795). Belonging scores increase from pre-test to post-test for both groups. Belonging scores in the post-test survey significantly predicted the following fall enrollment (F(1175) = 21.08, $p < 0.001$). And the post-test belonging score significantly predicted continued enrollment for treatment participants (β = −0.76, z = 2.49, p = 0.013). The belonging moderation analysis demonstrates the interaction between intervention and belonging, leading to increased continued enrollment (Table 3).

Table 3. Moderation of BLI Student Continued Enrollment by Intervention.

Predictor	β	S.E.	z	p	95% CI [LB, UB]
Belonging	−0.36	0.40	−0.90	0.368	[−1.13, 0.42]
Intervention	−3.62	1.60	−2.26	0.024	[−6.76, −0.48]
Belonging x Intervention	1.11	0.50	2.23	0.026	[0.13, 2.09]
Belonging x Control	−0.36	0.40	−0.90	0.368	[−1.13, 0.42]
Belonging x Treatment	0.76	0.30	2.49	0.013	[0.16, 1.35]

The intended effect of the intervention treatment was on students' feelings of belonging in engineering. Belonging on its own did not significantly predict continued enrollment (Table 3). However, the interaction between belonging and treatment demonstrated a moderation effect. Students in the intervention treatment were significantly more likely to continue enrollment in engineering at higher scores on the belonging scale (Figure 4).

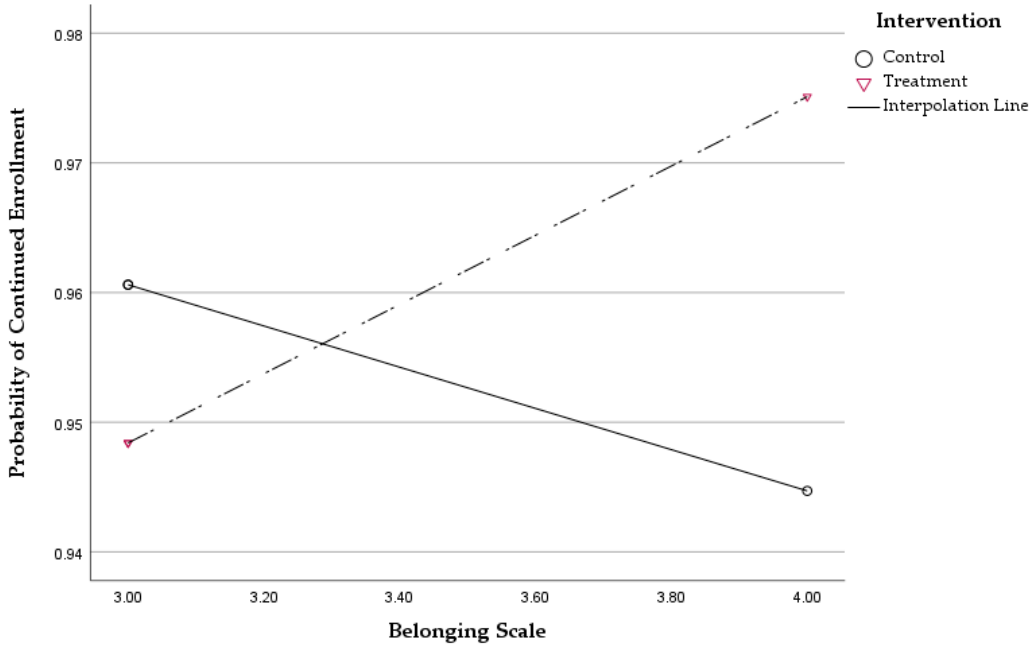

Figure 4. Probability of continued enrollment at different levels of belonging by intervention group.

4. Discussion

The intervention is intended to support BLI students in their academic success within the course as well as longer-term persistence by developing feelings of belonging in engineering. The moderation effects of the intervention for BLI students and for belonging on continued enrollment in engineering demonstrate the utility of ecological belonging intervention in engineering classrooms. In both instances, the participants in the ecological belonging intervention had a significantly increased probability of continued enrollment in engineering courses during the fall term following the intervention compared to the control participants. The effects for BLI students demonstrate the efficacy of treatment for the targeted group, while belonging effects begin to demonstrate the potential mechanism of the treatment. These results support earlier findings with BLI students maintaining belonging scores and achieving higher MATLAB grades [67].

The ecological belonging intervention seems to serve as a protective mechanism against common negative experiences that may occur in the classroom environment to shape BLI student belonging experiences and persistence [75,76]. As discussed previously, lower retention and persistence of BLI students have been linked to experiences of marginalization, systematic discrimination, bias, and microaggressions [3–6,21,33,77]. The significant and positive difference in treatment and control groups for BLI student continuation demonstrates that intervention successfully improves the probability of continued enrollment—BLI students who did not receive the message that typical struggle was normal and surmountable with time and effort were much less likely to persist in engineering.

Retention of BLI students remains problematic and essential for continued growth in engineering [6,78,79]. Interventions such as ours provide an opportunity to improve the ecology of the classroom in ways that support BLI students in pursuit of engineering degrees. The intervention seeks to improve the classroom ecology by normalizing struggle and viewing struggle as surmountable through faculty and peers sharing experiences of overcoming difficulty, thereby improving connections and interactions between faculty and students, and between peers that increase beneficial student outcomes [3–7,17,57,58,62]. Black and Latinx American students lack same-race peers and faculty, thereby limiting their ability to identify with faculty, pressure to represent their race/ethnicity, and isolation from peers [17,28,62,80]. For Latina/o/x students, a sense of belonging to a community is an important cultural touchstone associated with the pursuit of higher education [80]. In engineering, holistic support encompassing academics, social aspects, and a sense of

belonging support was important for Latinx students' participation in an intervention program [6]. For first-year students, a sense of belonging in class relates to students' perceptions of the instructors' characteristics as well as campus-level belonging [57]. The sense of belonging then influences academic motivation [57]. Connections with mentors at the beginning of the first year of college resulted in higher academic self-efficacy and a sense of belonging at the end of the year [58]. Similarly, peer social interactions contribute to a sense of belonging with Black, Latinx, and Asian Pacific American students reporting lower levels of belonging than white students in the first year of college [3]. A strong sense of belonging for Black students is associated with a strong intention to persist in college [4,5] with beneficial outcomes [49,50].

Addressing classroom ecology disrupts the systematic exclusion and marginalization that threaten belonging for BLI students [17,43,68]. Increasing the sense of belonging may lower the impact of minoritizing experiences not faced by white peers [17,43]. Black women's sense of belonging is disrupted by systematic racial and gender discrimination and microaggressions that isolate and marginalize them in an already minoritized group in science and engineering [19]. The improvement of classroom ecology complements support from communities outside of the classroom such as identity-based affinity groups and communities beyond engineering [21,59,60].

The moderation of belonging demonstrates the potential of psychosocial interventions on persistence in engineering found in other spaces [52,53]. The intervention seeks to alter the classroom ecology to provide an environment in which academic struggle is normal and surmountable such that overcoming challenges is also normalized and encouraged. One possible effect of this kind of normalization is students recognizing that their peers struggle and that they belong despite their struggles [17,43], thereby increasing their sense of belonging to the same group. Encouraging students to see the classroom as a social group can support students' views of themselves as belonging to the social group. Group members being part of a social group represents their belonging [4,81]. Recognizing the struggle of peers and faculty helps students see those around them as individuals. This leads to a recognition of students and faculty as a "whole person" and provides opportunities for connections between faculty and students and between students [46,62]. In contrast, distant or unapproachable engineering faculty contribute to lower student self-efficacy, academic confidence, and course GPA [61]. When faculty bring their personal experiences into the classroom, students can see how personal and social experiences can influence coursework [19,61,62].

The ecological nature of the intervention supports many factors that contribute to the influence of belonging on continued enrollment. The results provide some promising evidence in support of previous analyses [67] that the intervention supports students' feelings of belonging in the classroom to support persistence. Other possible related mechanisms warrant further investigation. In particular, the intervention may also support messages of a growth mindset for students and instructors. A growth mindset is to think of intelligence and skills as things that can be nurtured rather than fixed or innate abilities [82]. Prior research has demonstrated that STEM instructors who hold fixed mindsets have equity gaps by race/ethnicity and gender in their courses [83,84]. The presence of this thinking can shape a variety of social interactions in the classroom that convey messages about the types of people who can succeed. Similarly, students with a growth mindset may interpret challenges as opportunities for growth rather than a threat or confirmation of a lack of ability to succeed [85,86]. Other research has demonstrated that growth mindset interventions may result in similar types of outcomes [87]. Our future work includes investigating these other mechanisms that may further support or differ from the belonging uncertainty mechanisms, which this study focused on. We are collecting quantitative and qualitative data to better understand how the intervention works in this course context and across other courses.

It is important to note that this intervention is not a panacea for all the systemic inequities occurring in engineering or STEM environments more broadly. Instead, this intervention adds to the toolkit that researchers and educators may use to provide support for marginalized students to better support their experiences and progress through degree programs. Future research with larger BLI samples should seek to demonstrate the moderation effects on belonging, specifically in BLI students as well as other minoritized students. Similarly, connecting ecological belonging to improved academic performance for BLI students could provide an important opportunity to address achievement gaps in more advanced courses, as well as the longitudinal effects of the belonging intervention.

5. Conclusions

Engineering degree completion rates for BLI students continue to lag behind those of their peers, attributable in part to unwelcoming engineering environments. This study employed an ecological belonging intervention to examine the moderating effects of the intervention on continued enrollment in engineering the semester following its implementation. The moderation of continued enrollment following our ecological belonging intervention demonstrates the utility and importance of faculty facilitating classroom norms and expectations for student belonging. Although still in the developmental research stage, this intervention holds promise as a significant opportunity to support and increase the sustained enrollment of BLI students in engineering.

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