Student Perceptions of a Belonging Intervention

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Introduction

This full empirical research paper investigates the connection between an ecological belonging intervention, programming self-efficacy, and course grade for first-year engineering students. Improving the retention of undergraduate students in engineering pathways requires clear frameworks that include predictors and influences on continued enrollment in engineering courses. The persistence of Black, Latiné, or Indigenous (BLI) students remains lower than their peers and disproportionate to the U.S. population [1]. The persistence of engineering students remains a major concern with BLI students demonstrating disproportionate attrition in comparison to White and Asian peers. This increased attrition from engineering pathways is often related to systematic exclusion and marginalization in engineering environments [2]-[5]. While some progress has been made in addressing these issues, progress, and representation have remained disproportionate and uneven due to the multifaceted nature of the problem [4]. Pathways into and through engineering are influenced by students' reasons for pursuing engineering, education experiences, career motivations, as well as social and cultural signals around who belongs in engineering [2], [3], [5]-[11]. BLI students face a wide range of messages that they do not belong in engineering spaces. These include discrimination, systemic racism, stereotyping, and microaggressions [2], [6], [7], [8], [10], [12]-[15]. These messages become compounded at Predominately White Institutions (PWIs), in which the whiteness embodied in engineering culture, education, and spaces is pervasive and normative [16]-[21].

Academic performance represents one of the strongest predictors of continued success and enrollment [2], [22]-[25]. Alone, performance measures insufficiently predict persistence in engineering and reflect biased measurements of competence that selectively disadvantage BLI students [25]-[28]. Deficit-based interventions frame students as in need of alteration rather than the systems that generate and perpetuate inequities [29], [30]. As such, deficit frameworks fail to address the ecological context of engineering classrooms that shape students' development and persistence choices. Therefore, interventions addressing the ecologies and messages that support self-efficacy beliefs can generate environments that better support engineers and narrow the race and ethnicity-based self-efficacy gaps observed in these contexts [22], [24].

Many influences on course performance also contribute to students' persistence in engineering. Students' beliefs about belonging in engineering have been strongly linked to persistence in engineering [31], [32], [33]. Similarly, a student's self-efficacy in relevant topics influences persistence [34], [35], [36]. This work identifies relationships between student perceptions of an ecological belonging intervention, programming self-efficacy, and course grade in an introductory first-year engineering programming course. Our research questions were 1) How well does participating in the intervention predict course grade? 2) How does viewing the activity as useful influence course grade? And 3) How does the recommendation that the activity be continued influence course grade? We tested the predictive relationships between these variables with a series of path analyses, a form of structural equation modeling.

Theoretical Framework and Background

Theoretical Framework

Self-enhancement and self-protection provide an opportunity to understand why students may find the intervention useful or recommend it without necessarily recognizing the benefit of the intervention for themselves. Self-enhancement provides the self with an opportunity to positively assess performance to maintain or enhance one's self-assessment of competence [37]. Self-protection functions to protect self-assessment to ensure it does not fall below a tolerable level as a form of damage control [37]. Together, self-enhancement and self-protection preserve and promote self-assessment through related, but disparate mechanisms. While rooted in self-assessment, each is constrained by reality [38]. An individual may fail to reconcile an objective assessment with a self-assessment and seek to identify external explanations for the mismatch in self-assessment and objective assessment [38], [39].

Our research questions test psychosocial processes to identify the relationships between student perceptions of our ecological social belonging intervention, programming self-efficacy, belonging, and course grades. Self-efficacy represents the concept that individuals have beliefs about their capability to complete specific behaviors to achieve goals successfully [40], [41], [42]. As such, individual self-efficacy beliefs direct behaviors and efforts to successfully achieve those goals [42], [43]. Broadly, self-efficacy directly relates to success in STEM courses, however, some variation for women, Black, and Latiné students has been demonstrated [5], [7], [10], [44], [45], [46], [47]. Individuals may hold different levels of self-efficacy for specific knowledge and skill domains. Programming self-efficacy represents one such domain essential for first-year engineering students.

Programming Self-Efficacy

Programming self-efficacy (PSE) reflects students' beliefs about their ability to complete programming behaviors and complete programming-based coursework. PSE impacts student behaviors and success in engineering and computer science pathways [48]-[53]. Experience with computing and programming predicts the related self-efficacies [54]-[57]. However, access to programming instruction remains inconsistent, contributing to disparities in PSE [58]-[61]. Students with lower PSE beliefs leave computer science and programming courses at higher rates than those with higher PSE beliefs [48], [49], [62]. Early required engineering coursework reflects the importance of programming skills and knowledge with courses that focus on developing programming knowledge and skills. For example, coursework required for advanced, discipline-based courses requires programming skills typically demonstrated through proficiency in MATLAB. Self-efficacy beliefs developed during such coursework contribute to PSE development. However, additional factors that support or disrupt PSE development play important roles. For example, strong social belonging in STEM contexts has been linked to self-efficacy development [63]-[66].

Disparities in self-efficacy exist between students holding different racial and ethnic identities. For example, the lower self-efficacy beliefs reported by Asian students do not predict reduced academic performance [67]. Black and Latino men tend to express higher general self-efficacy, but lower academic self-efficacy [68]. BLI students tend to express lower academic self-efficacy than their White peers, however, disadvantaged BLI students tend to express lower self-efficacy than wealthier peers of the same race [69]. Some interventions that boost self-efficacy for White

students do not affect other students thereby limiting their applicability to closing race and ethnicity-based self-efficacy gaps [63].

Social Belonging

Students' feelings of being connected to peers and academic institutions reflect their social belonging [70], [71]. In college settings, strong social belonging predicts academic achievement, adjustment, and retention [63], [70]-[77]. Conversely, lower social belonging beliefs or belonging uncertainty disrupts learning gains [68], [78] and impairs performance [79]. The influence of belonging on academic performance is stronger than that of a broad range of other psychosocial constructs, including factors like instructor and peer support [80]. Data suggests that belonging and academic performance in STEM form feedback loops, strengthening or weaking one another recursively [81]. Due to this, it is especially critical to support students' belonging when it is at its weakest: during the first years of engineering study [82], [83], [84]. Unfortunately, due to strong and complex links between belonging, identity, and performance [85], [86], [87], engineering environments that marginalize one's identities exert a powerful negative effect on social belonging. [80], [84], [88]. Resultantly, students with experienced or anticipated low belonging express less certainty about entering [89] or remaining in engineering [90]. Finally, students with lower belonging tend to hold lower self-efficacy beliefs [63], [64] and face systemic barriers to success in engineering [63], [73], [74], [91].

Methods

The analyses presented here are a part of a larger research project investigating the effects of a psychosocial belonging intervention designed to address inequities in student outcomes. Students in a first-year engineering fundamentals course completed surveys before and after an ecological belonging intervention. The ecological belonging intervention is focused on supporting BLI students in engineering through narratives developed to address common areas of challenge for early career engineering students. This intervention aims to normalize typical college struggle in the target course and disrupt social belonging uncertainty that we hypothesize leads to equity gaps in students' beliefs about their abilities to succeed on programming tasks, and ultimately, student grades within the course. As part of quasi-experimental research, 718 students completed surveys assessing programming self-efficacy, belonging, and participant perceptions of the intervention. Specifically, participants reported whether or not they found the intervention activity useful and if they would recommend the activity be continued. This study examined the relationship between perception of the intervention, programming self-efficacy, belonging, and course grades for BLI students. The analyses presented here represent exploratory work to identify construct relationships between the perception of the intervention and course outcomes such as programming self-efficacy and course grade.

Procedures

In the Spring of 2024, students enrolled in the engineering course received an email invitation to complete an online survey via Qualtrics. Five sections were included with four sections receiving the intervention/treatment and one section acting as a control. The pre-test survey was administered before students participated in a class-based belonging intervention during the first week of classes. The ecological social belonging intervention is described in detail elsewhere [92]-[95]. Briefly, the intervention informs students that struggle is normal, and surmountable given time and persistence and signals that others students have struggled in this course and still succeeded. The

intervention demonstrates that struggle does not indicate students do not belong in the course or engineering more broadly. The ~40-minute intervention includes individual reflection, stories of students who previously took the course, and small and large discussions (for more information about the intervention, refer to [94]). Students received the post-test survey in the 14th week of the semester. Students were awarded two extra credit points for the course for each survey they opened. The Institutional Review Board approved the study procedures.

Participants

Approximately 718 students were enrolled in the participating sections. Participants who did not pass an attention check question were removed from the data, as were students who did not respond to items required for these analyses. The initial analytical sample included 668 students. Participants self-identified demographics by selecting from categorical response options including write-in text options in the survey. Participant self-reported race/ethnicity, gender identity, nationality, sexual identity, and disability status are reported in Appendix 1. These characteristics are similar to those seen in the aggregate undergraduate engineering population [96], [97].

Measures

Our analyses investigated the intervention mechanisms in our target population: Black, Latiné, and Indigenous students. Self-reported race/ethnicity was used to determine BLI membership. The BLI group includes all participants who selected Black or African American, Latiné, Native American or Native Alaskan, Pacific Islander, and participants who selected one of these and any other option. We acknowledge that this aggregation erodes the unique experiences of individual BLI students and their identities; however, it simultaneously reveals shared patterns of marginalization.

Programming Self-Efficacy survey items were adapted for coding courses [98]. The mean of five items represented programming self-efficacy. An item example is, "I can figure out how to finish a coding class project at home." Participants responded on a 4-point scale (with coding values shown in parentheses): I'm very sure I CANNOT do it (1); I'm somewhat sure I CANNOT do it (2); I'm somewhat sure I CAN do it (3); I'm very sure I CAN do it (4). The scale exhibits good internal reliability (Cronbach's $\alpha = .84$).

Belonging in Class was measured with the mean of four items adapted for the engineering context [90]. The item stem read: "Take a moment and think about your experiences and feelings related to engineering. To what extent do you agree with the following statements?" An example item is: "I feel comfortable in engineering". Participants responded to these items with a four-point Likert agreement scale: Strongly disagree (1), Disagree (2), Agree (3), Strongly Agree (4), or I haven't had any engineering courses (missing). The items demonstrate good internal reliability (Cronbach's $\alpha = .82$).

Course grade was collected from instructor-provided data and represented the final grade of the student as a percentage and *Intervention condition* was identified based on institutional data and coded as control (0) and treatment (1) based on section of enrollment.

Participants responded to an item to check if they recalled the intervention activity: "During the first week of the semester, several sections completed a discussion activity in class. Do you recall what this activity was about?" Participants who selected the correct response were asked two additional items about the usefulness of and their recommendation for the intervention.

Intervention usefulness was measured with a single item, "To what extent did you find the activity at the beginning of the semester to be useful?" Participants responded on a 4-point scale: Not useful at all (1); Somewhat useful (2); Useful (3); or Extremely useful (4). *Intervention recommendation* was measured with a single item, "To what extent would you recommend that engineering instructors continue to run this activity in future semesters?" Participants responded on a 4-point scale: Do not recommend at all (1); Somewhat recommend (2); Recommend (3); or Strongly recommend (4).

Positionality

The authors represent a subset of researchers from the larger intervention project [95]. The project as a whole represents the larger research team's interest in diversity, equity, inclusion, and justice in engineering. The research presented here focuses our interests on BLI students, a group of which some of the larger research team are members and others are not. As authors, we recognize our positions of privilege in academia and hold these in tension as we seek to investigate the perspectives, attitudes, and experiences of current undergraduate engineering students. The larger research team members are highly educated, identify as White, Black, or Latiné, and identify as men, women, and gender minorities. Our academic and research training spans engineering, higher education, and psychology. The breadth of our backgrounds provides a diverse range of personal and professional perspectives. Further, we value quantitative analyses while recognizing its limitations in understanding individual experiences, which can best be investigated through qualitative means. We seek to identify representative patterns of experience that can be used to improve persistence and degree completion for students.

Analysis

Descriptive statistics for study variables including means, standard deviations, kurtosis, skew, and bivariate correlations were calculated using SPSS. The main analyses were conducted in Stata v.17. The analyses used path analysis in a structural equation modeling framework with full information maximum likelihood estimation to account for any missing values. Path analysis extends multiple regression techniques to test a set of multiple dependent variables in a specified structure [99], [100]. The structure to be tested is proposed by researchers in an analytic method to determine how well the proposed model represents the empirical data (i.e., model fit) and how well the model explains variation in the outcome variable. Path analysis is particularly useful when variables mediate other relationships in the model [100]. In this project, we identify the variable relationships with intervention conditions, usefulness rating, and recommendation rating via the model proposed in Figure 1. This model is based on the influence of self-efficacy on belonging and their shared influence on course grades.

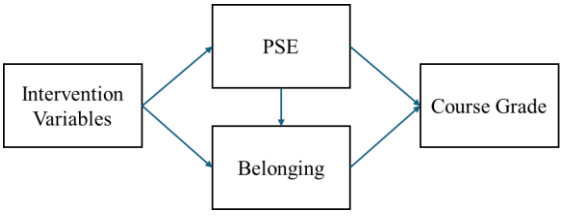

Figure 1. Model tested with intervention variables.

We assessed the fit of the model with several fit statistics including the chi square, root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and the standardized root mean square residual (SRMR). The coefficient of determination (CD) corresponds to the variation in the outcome variable accounted for by the model. Established guidelines for each fit statistic indicate models that meet the following fit the data well: non-significant chi-square, RMSEA

less than .07 (using a 95% confidence interval [CI]), CFI greater than .95, TLI greater than .95, and SRMR less than .05 [101].

Results

The descriptive statistics and bivariate correlation for study variables are presented in Table 2.

Table 2. Variable mean and standard deviation by intervention condition and Pearson correlation.

Variable	Treatment		Control		Bivariate Correlation			
	m	SD	m	SD	1	2	3	4
1. PSE	3.27	1.09	2.87	3.06	-			
2. Belonging	3.08	1.33	2.91	2.74	0.03	-		
3. Course Grade	0.88	0.11	0.89	0.09	0.08	0.04	-	
4. Utility	2.1	0.72			0.06	.18**	-0.01	
5. Recommend	2.41	0.78			0.03	.28***	0.04	.63***

Note: Bivariate correlation 2-tailed significance value: *** indicates $p <$ .001, ** indicates $p < .01$, and * indicates $p < .05$.

Intervention Condition Model

The model tests the influence of the intervention by comparing the treatment and control conditions fit the data well with acceptable, but not excellent fit statistics (Table 3). However, the coefficient of determination indicates the model explained a small portion of the course grade variation for BLI students. The model indicated a direct, significant, and meaningful direct connection between PSE and belonging, and PSE and course grade (Table 4, Figure 2). However, no significant direct or indirect effects were identified for the intervention condition.

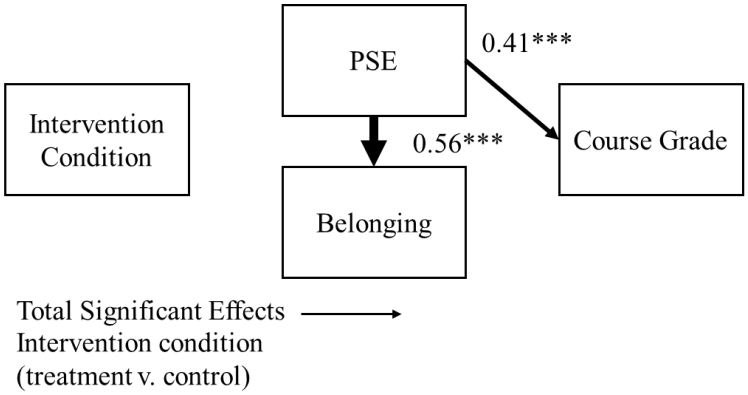

Figure 2. Construct relationships for intervention condition on course grade via programming self-efficacy (PSE) and belonging. Note: All figures present standardized coefficients that are reported with their significance value: *** indicates p < .001, *

Table 3. Fit Statistics for intervention model, utility model, and recommendation model.

Model	Chi-Square (p)	RMSEA	LB UB	AIC	BIC	CFI	TLI	SRMR	CD
Treatment	3.25 (.071)	0.17	0.00, 0.40	88.62	114.26	0.95	0.69	0.06	0.05
Utility	1.71 (.191)	0.15	0.00, 0.54	86.18	101.96	0.98	0.86	0.05	0.14
Recommend	0.09 (.760)	0.00	0.00, 0.33	74.13	89.91	1	1	0.01	0.40

Note: LB and UB indicate lower and upper bound RMSEA values.

Table 4. Intervention model coefficients.

Dependent	Independent	β	B	S.E.	z	*p*
		Direct Effects				
PSE	Condition	-0.20	-0.20	0.14	-1.75	0.080
Belonging	PSE	0.56	0.57	0.10	5.71	< .001
	Condition	0.07	0.09	0.12	0.76	0.449
Course Grade	PSE	0.31	0.06	0.02	2.52	0.012
	Belonging	0.18	0.03	0.02	1.44	0.150
		Indirect Effects				
Belonging	Condition	-0.10	-0.10	0.08	-1.67	0.094
Course Grade	PSE	0.10	0.02	0.01	1.40	0.163
	Condition	-0.10	< -0.00	0.01	-1.25	0.210
		Total Effects				
PSE	Condition	-0.20	-0.20	0.14	-1.75	0.080
Belonging	PSE	0.56	0.57	0.10	5.71	< .001
	Condition	-0.00	-0.10	0.15	-0.31	0.754
Course Grade	PSE	0.41	0.08	0.02	3.91	< .001
	Belonging	0.18	0.03	0.02	1.44	0.150
	Condition	-0.10	< -0.00	0.01	-1.25	0.210

Intervention Utility Model

The model to test the influence of the students' rating of the intervention as useful or not fit the data well (Table 3). The coefficient of determination indicated the model explained a considerable course grade variation for BLI students. This model identified similar patterns of significance as the intervention model with significant direct effects between PSE and belonging, as well as PSE and course grade (see Table 5, Figure 3). Like the intervention model, no direct or indirect effects linked usefulness rating to course grade.

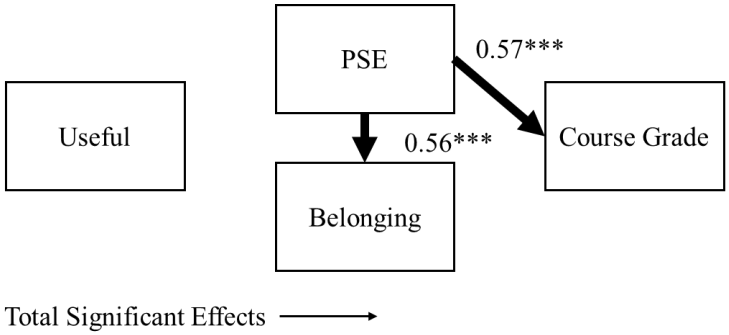

Figure 3. Construct relationships for intervention usefulness rating

Table 5. Utility model coefficients.

Dependent	Independent	β	B	S.E.	z	*p*
		Direct Effects				
PSE	Useful	0.21	0.15	0.13	1.19	0.235
Belonging	PSE	0.58	0.60	0.14	4.33	< .001
	Useful	0.24	0.18	0.10	1.81	0.070
Course Grade	PSE	0.41	0.07	0.03	2.24	0.025
	Belonging	0.27	0.05	0.03	1.47	0.142
		Indirect Effects				
Belonging	Useful	0.12	0.09	0.08	1.15	0.252
Course Grade	PSE	0.16	0.03	0.02	1.39	0.164
	Useful	0.18	0.02	0.02	1.56	0.118
		Total Effects				
PSE	Useful	0.21	0.15	0.13	1.19	0.235
Belonging	PSE	0.58	0.60	0.14	4.33	< .001
	Useful	0.37	0.27	0.12	2.19	0.028
Course Grade	PSE	0.57	0.10	0.03	3.87	< .001
	Belonging	0.27	0.05	0.03	1.47	0.142
	Useful	0.18	0.02	0.02	1.56	0.118

Intervention Recommendation Model

The model to test the influence of the students' recommendation for the intervention to be continued fit the data very well (Table 3). The coefficient of determination indicated the model explained a large portion of the course grade variation for BLI students. This model identified unique patterns of significance with both significant direct and indirect effects for recommendation rating (Table 6, Figure 4). The probability of recommending the intervention directly predicted an increase in PSE and belonging and indirectly predicted an increase in course grade.

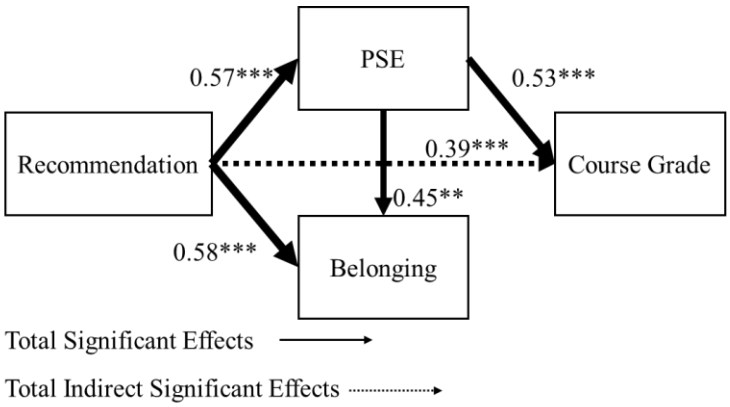

Figure 4. Construct relationships for intervention recommendation rating on course grade via programming self-efficacy (PSE) and belonging.

Table 6. Intervention recommendation model coefficients

Dependent	Independent	β	B	S.E.	z	*p*
		Direct Effects				
PSE	Recommendation	0.57	0.41	0.11	3.84	< .001
Belonging	PSE	0.45	0.46	0.16	2.86	0.004
	Recommendation	0.32	0.24	0.12	2.03	0.043
Course Grade	PSE	0.41	0.07	0.03	2.24	0.025
	Belonging	0.27	0.05	0.03	1.47	0.142
		Indirect Effects				
Belonging	Recommendation	0.26	0.19	0.08	2.29	0.022
Course Grade	PSE	0.12	0.02	0.02	1.31	0.192
	Recommendation	0.39	0.05	0.02	3.12	0.002
		Total Effects				
PSE	Recommendation	0.57	0.41	0.11	3.84	< .001
Belonging	PSE	0.45	0.46	0.16	2.86	0.004
	Recommendation	0.58	0.43	0.11	3.94	< .001
Course Grade	PSE	0.53	0.10	0.03	3.51	< .001
	Belonging	0.27	0.05	0.03	1.47	0.142
	Recommendation	0.39	0.05	0.02	3.12	0.002

Discussion

The intervention and usefulness rating models did not reveal any significant relationships between experiencing the intervention or students' perceptions of the intervention's usefulness on their final course grades. However, both models supported significant connections between PSE and belonging, and PSE and course grade. These connections, regardless of students' intervention experiences, indicate the importance of self-efficacy for students feeling that they belong in engineering courses and the influence self-efficacy has on academic performance.

The recommendation model indicated a strong connection between the recommendation that the intervention be continued and students' course grades that was mediated through PSE. The connection between recommending the intervention to others and one's own self-efficacy presents a new opportunity to understand how interventions may influence outcomes, such as course grades, even when participants did not consciously assess that a particular intervention was useful for themselves. Further, the lack of treatment effects suggests that mere exposure to an intervention is insufficient to guarantee its efficacy on an individual. Rather, the belief that others should be exposed to the intervention is a far more accurate signifier of treatment efficacy on an individual.

An explanation for this unusual phenomenon lies in a reflexive interpretation of the intervention– it was not useful for me, but useful for others and therefore should be continued. The principles of self-protection and self-enhancement explain this phenomenon. Self-protection operates to improve one's assessment of competence whenever it may be reduced below a tolerable level [37]. Students who did not see the intervention as useful may have rejected it to protect their self-assessed competence in the course. Self-enhancement provides a parallel process in which individuals seek to maintain or enhance self-assessed function [37]. Participants with higher self-

assessments may interpret the intervention as beneficial for those worse off than themselves. As such, the combination allows for the rejection of personal utility while recognizing a benefit for others.

Future Work and Limitations

A limitation of this work lay in the disparate size of the quasi-experimental groups. This difference in group size may have influenced the detection of significance in the intervention model. Similarly, the disparity in the size of BLI groups limited our ability to identify differences between Black, Latiné, and Indigenous students in their perception of the intervention and its effects on PSE, belonging, and course grades. One solution is further research to evaluate these relationships with a larger group of BLI participants. In addition, more complex models that include meaningful constructs, such as engineering identity, might more completely explore these important relationships.

Conclusions

This study examined student perceptions of an ecological belonging intervention aimed at supporting women and Black, Latiné, and Indigenous (BLI) students in an introductory engineering programming course. The intervention was designed address inequities in student outcomes normalizing the common academic struggles students experience, such as time management challenges, difficulties in working within engineering teams, and the complexities of learning programming. The intervention sought to frame struggles within the course context as temporary and surmountable with effort and time, rather than as signs of personal inadequacy or a lack of belonging in the field.

Course grades were not directly affected by treatment or by participants' assessment of the treatment's utility. However, the strength with which participants recommended the intervention be continued significantly predicted PSE, belonging, and course grade. These findings highlight the importance of how students interpret and engage with belonging interventions, underscoring the potential for tailoring such interventions to meet the specific needs of first-year engineering students. By fostering a sense of belonging and boosting self-efficacy, interventions like this one can play a crucial role in supporting underrepresented groups in engineering and improving their academic persistence and success. This study offers valuable insights into the efficacy of belonging interventions in engineering education. By examining how students perceive and engage with these interventions, the research contributes to the development of strategies that can be refined and customized to better support diverse student populations, ultimately enhancing their sense of belonging and academic performance in STEM fields.

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Appendix 1

Table 1. Demographic Characteristics for Participants.

Race/Ethnicity		Gender		Sexual Identity		Disabilities/ Learning	
African American/ Black	17	Man	391	Heterosexual/ straight	503	Learning Disability	19
American Indian/ Alaska Native	3	Women	178	Asexual	5	ADHD	58
Arab, Middle Eastern, or Persian	10	Nonbinary	3	Bisexual	31	Autism Spectrum	14
East Asian	44	Another Gender Identity	1	Gay	1	Physical Disability	15
Southeast Asian	14	Prefer not to Respond	12	Lesbian	6	Chronic illness/ condition	28
Indian, Pakastani, Bangladeshi	78			Pansexual	4	Psychological condition	67
Another Asian Identity	1			Queer	2	Another Disability	3
Mexican American, Chicao, or Mexican	2			Another Sexual Identity	1		
Central American	2			Prefer not to Respond	32		
South American	14						
Puerto Rican	7						
Another Latinx	5						
Native Hawaiian/ Pacific Islander	3						
White/ Caucasian	277						
Another Race/ Ethnicity not listed	2						
Prefer not to Respond	13						
More than one of these	93						