Exploring the Impact of Math Performance on Sense of Belonging following a Summer Bridge Program

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Abstract— **This full-length research paper describes a retrospective analysis of engineering students' sense of belonging following a summer bridge program (SBP) and as related to their first-semester math performance. The Brown Forman Engineering Academy (BFEA) is a two-week, no-cost SBP designated to enhance college readiness for first-year students at the University of Louisville who are underrepresented and underprepared (e.g., low-income, race, gender) for engineering school. The program aims to support students in calculus, foster community growth, and develop a sense of belonging on campus. This study assessed the success of the BFEA program by evaluating participants' sense of belonging at the beginning of the first semester. In addition, this study examined how students' sense of belonging was influenced by their first-semester math grades. Results indicated that at the beginning of the fall semester, there was no significant difference in the sense of belonging between BFEA participants and the broader student body. Additionally, math performance affected students' sense of belonging, even following the SBP, similarly to the full incoming student cohort. It is possible that students entered this program with very low belonging, and that it raised them to the average cohort level. It is also possible, however, that an improvement in belonging did not occur during the program. It is not possible to fully determine the impact of BFEAfrom this data, because there was no pre-program assessment of belonging. More research is needed to investigate the SBP as a causal force on students' sense of belonging.**

Keywords—sense of belonging, summer bridge program, engineering education, math performance, underrepresented student persistence

I. Introduction & Literature Review

To increase the diversity of the engineering workforce, diverse students need to be retained in engineering programs. Many interrelated factors lead to a student's decision to persist, including individual attributes, perceptions, and experiences, and the college environment. One highly predictive factor for all students is first-semester performance in mathematics; students who receive a high grade (A or B) in their first math course tend to persist, whereas students who receive a low grade (D, F, or W) are more likely to leave engineering than to stay [1], [2], [3], [4]. In addition non-academic factors, such as academic isolation, social isolation, cultural isolation, negative stereotypes related to ethnic identity, motivational vulnerability, financial insecurity, and discrimination, can impact students [5], [6].

While math performance affects all students, systemically underrepresented students, including those from low-income backgrounds, those facing racial disparities, and those encountering gender barriers, often contend with greater adversity compared to their counterparts in the majority. High-school high performing students from underrepresented populations statistically underperform academically, raising questions about these additional barriers. For underrepresented students, the risk of isolation is high when attending a new school, and even one instance of exclusion from peers can affect their academic achievements.

However, research has revealed that intervening to improve students' sense of belonging can offset some of these non-academic barriers for systematically underrepresented students, and even improve student academic performance in the first semester [7]. The term "sense of belonging" refers to a person's subjective feeling of being valued and trusted by another person or group, and mutually valuing and trusting that group [8]. Human beings thrive on relationships and the sense of belonging they provide [9]. Therefore, some of the non-academic barriers for systematically underrepresented students may be countered by a strong sense of belonging on campus or within a community.

A. Summer Bridge Programs

One potentially strong method of fostering both mathematics performance and perception factors such as sense of belonging is a summer bridge program (SBP). SBPs are weeks-long programs prior to the first year of college that introduce students to the rigor of college-level coursework and to the study skills necessary to succeed [6]. For example, the University of Wisconsin-Milwaukee hosts a 4-week bridge initiative designed to enhance the math placement of incoming freshmen with admissions or scholarship conditions, ultimately aiming to elevate persistence and graduation rates [10]. In this program, students engage in 2.5 hours of daily math coursework utilizing the Aleks program. Research on the program showed a positive impact on persistence and graduation rates, particularly for students with an ACT score of 27 or below (underprepared students). Subsequent investigations revealed that students with higher ACT scores tended to fare better academically on campus while individuals with lower scores improved math scores at an increased rate.

Virginia Tech conducts a summer bridge program with the goal of providing students with a comprehensive experience to enhance academic skills, familiarize themselves with campus, and foster personal and developmental growth. Qualitative analyses showed that completion of the 5-week program increased students' empowerment and success on campus [11]. Similarly, Georgia Tech's SBP, focused on students from underrepresented populations, has been shown to improve academic performance, bringing performance to the same level as peers' in majority populations. Additionally, underrepresented students who participated in the program were more likely to be retained [5].

Another noteworthy program at the University of Michigan, modeled by the Meyerhoff Program (a multicomponent program aimed at increasing the representation and academic achievement of talented underrepresented students in STEM fields [12]), spans 2 years with a 5-week summer component, aligning closely with the goals and activities of the SBP in this study. This program aimed to understand the social outcomes of undergraduate engineering bridge programs. Their research emphasized the importance of underrepresented students and women feeling connected, which correlated with their persistence. The program found several significant insights: female participants had stronger connections to the program than male students, resilience levels varied by gender, women and underrepresented students were more likely to seek or accept social support, and increasing the number of women participating in a bridge program enhanced the sense of belonging for women in engineering [13].

II. Our SBP

The Brown Forman Engineering Academy (BFEA) is the SBP at the J.B Speed School of Engineering. BFEA is a two-week, no-cost, live-on-campus program designed to enhance the readiness of first-year students who are underrepresented and underprepared. The program aims to support students in calculus, foster community growth, and develop a sense of belonging on campus. In addition to math training, program activities include formal and informal interactions will numerous faculty members and campus resources. This study pertains to the 2022 and 2023 BFEA cohorts.

A. Application process for BFEA

Each summer, the cohort size for BFEA consists of 48 students and 6 mentors. To apply, students must already be accepted to the university, and they must complete an online application where they are asked to write a short essay responding to the prompt: "Please tell us about yourself and how the Brown Forman Engineering Academy will help you transition into the Speed School of Engineering."

For the 2022 cohort, eligibility for BFEA mandated enrollment in specific math courses upon entry. These courses comprised engineering math courses equivalent to college algebra, precalculus, and calculus I. In addition, students pursuing either an engineering Bachelor of Science or a Bachelor of Arts in Computer Science were eligible for acceptance into the program in 2022. For the 2023 cohort, eligibility criteria were slightly different; students were required to be enrolled in either precalculus or calculus I, and they were required to be pursuing an engineering Bachelor of Science degree.

B. Math Instruction

The BFEA program offered a math program comprising of two, 2-hour sessions in the morning and afternoon, Monday through Friday. Therefore, upon the completion of the program, students had received at least 32 hours of math review. These sessions were led by Resources for Academic Achievement mathematics staff and are centered around a Pearson® electronic textbook, that had been designed for specific courses at the J.B Speed School of Engineering. The math curriculum in BFEA was heavily algebra-based, giving students the opportunity to review crucial materials necessary for enrolling in various math courses such as precalculus and calculus I. The curriculum followed an emporium model in which students worked at their own pace on a series of homework assignments and quizzes in a classroom with instructor resources available as needed [14]. Receiving an average score of 80% or higher on assignments was required to progress, and completing a certain number of assignments was required before gaining access to exams. Throughout these math sessions, two instructors were present in the room, circulating to assist students with any questions or problems they encountered.

C. Community Growth

Creating a sense of community growth is challenging, requiring many informal and formal interactions [13]. Upon their arrival, students were placed into groups consisting of seven other students, each assigned to an upper-class mentor who provides formal mentorship. These mentors undergo an application process and numerous hours of training to ensure they are equipped to guide students through the program and assist with the transition into college life. Within these mentor groups, nightly reflection sessions are held where students engage in guided discussions, reflecting on the day's activities, lessons learned, and concerns they may have regarding entering college. Over time, these mentor groups develop strong bonds and have been described as a close-knit family. Also, students can regularly interact with peers from other groups, fostering a broader sense of community within the program. Throughout the program, students participate in team building and leadership activities including a campus scavenger hunt, hands-on engineering challenges, and a final presentation. Additionally, numerous social events are organized, including going to an escape room, attending a sporting game, and game nights. An important aspect that helps students feel connected once the semester begins is their class assignment. All students who complete the program are placed in block classes together during their first year. This intentional grouping allows students to sit with familiar faces and typically leads to study groups forming, and significantly easing any nerves they may have about starting classes.

D. Sense of Belonging Activities

One of the overarching goals of BFEA is to cultivate a strong sense of belonging among students as they transition to full-time campus life. One such effort is to familiarize students with the campus and the greater area beyond campus by conducting campus resource visits, tours, and an interactive scavenger hunt. In addition, there were "meet and greet" sessions with a diverse

array of individuals they are likely to encounter on campus. This includes departmental professors, deans, and Student Success staff, such as advisors within the J.B Speed School of Engineering. These interactions help to connect students with key figures within the university community. Another method designed to enhance students' sense of belonging is through organized lab tours and introductions to various Engineering Student organizations. These experiences allow students to immerse themselves in the academic and social settings of the engineering community, facilitating a sense of inclusion and connection.

E. Current Study

Although the BFEA program has been designed to prepare students for math courses and for college in general, it has not undergone objective evaluation or assessment. The current study is the first step in this process, investigating available retrospective data on student sense of belonging and math performance in the first semester of engineering school. Our research questions were:

RQ1: Does BFEA participants average sense of belonging at the beginning of the fall semester differ from the incoming student cohort?

RQ2: Does first semester math performance affect the change in students' sense of belonging between the beginning and end of the semester for (a) the incoming student cohort, and (b) BFEA participants?

III. Methodology

A. Participants

The participants in this study were first-year engineering students at the University of Louisville who participated in the two surveys, and took ENGR 100 or 101 in Fall 2022 ($N = 199$) and Fall 2023 ($N = 241$). The students described included BFEA participants (Fall 2022, $N = 18$; Fall 2023, $N = 27$) and non-BFEA participants Reference Table 1 for the demographic breakdown for participants in the dataset.

Students were excluded from analysis if they withdrew from math in the first semester ($N = 116$), did not participate in one of the surveys ($N = 265$), or did not take one of the two math courses specified ($N = 151$). These students were not included in the samples stated above.

B. Materials

All students enrolled in a first-semester engineering methods course were invited to participate in a research study by completing a survey during class in Week 1 and Week 14. The survey questions were part of a larger research initiative aimed at identifying factors that predict student performance and retention in engineering. Students were informed that participation was voluntary, and they were given the option to accept or decline participation without facing any penalties. Additionally, students were assured that they could opt out of the research at any point by contacting the study's designated point of contact.

In the survey, students responded to questions related to Perceived Belonging Uncertainty as used by Weaver et al. [15], which was a focal point of analysis for this study. An example of one of the four questions (Cronbach's α = .84) is "I feel confident that I belong in engineering." Responses to these questions were recorded on a five-point Likert scale, from "Not at all true" (1) to "Completely true" (5). Higher scores indicated greater levels of perceived belonging uncertainty, while lower scores indicated lesser uncertainty.

TABLE 1: DEMOGRAPHICS FOR SURVEY PARTICIPANTS

Race	*N*, BFEA Participants	*N*, Non-BFEA Participants
Asian	28	7
Black/African American	10	2
Hispanic/Latino	15	7
Non-resident	4	1
Two or More Races	21	2
White	317	26
Female	93	25
Male	302	20

C. Procedures

This data analysis was retrospective. In Fall 2022 and Fall 2023, all engineering students enrolled in the first-year engineering course were invited to take the survey at the beginning and end of the semester (average response rates 94% and 81%, respectively). Some of these participants had completed BFEA the summer before their first year. We requested and received deidentified data for race, gender, BFEA math assessment scores, sense of belonging survey scores, and math course and performance data. We joined all data using research ids and ran all analyses using IBM SPSS®.

We first looked at belonging scores at the beginning of the semester, comparing the students who participated in BFEA to the student cohort. Due to the unequal sample sizes, we used Welch's Test for Unequal Variances to compare means. We then ran a predictive regression analysis to determine whether math course and performance predicted the change in belonging scores from the beginning to the end of the first semester. We added a BFEA flag to the analysis to determine whether it was a significant factor predicting sense of belonging with respect to math performance. In addition, a similar analysis was performed separately for BFEA participants.

IV. Results & Discussion

A. RQ1: Beginning-of-Semester Sense of Belonging

At the beginning of the fall semester, there was not a significant difference in the sense of belonging between BFEA participants and the broader student body, *Welsh's* $t(57.6) = -.85$, $p = .397$. Although a positive significant difference could have been interpreted as a benefit of the program, a lack of difference does not necessarily mean that the program had no impact. It is possible that students started the program with a significantly lower sense of belonging than the student cohort.

BFEA participation may have made a noticeable difference in their scores compared to the beginning of the program.

B. RQ2: Math Course and Performance, and Change in Sense of Belonging

The regression model indicated that students' change in sense of belonging from the beginning to the end of the first semester is significantly predicted by math course and performance, $F(2, 437) = 22.83$, $p < .001$, $R^2 = .09$. The math performance predictor was significant, $t(437) = -6.75$, $p < .001$, $B = -.31$, whereas the math course predictor (precalculus or calculus) was not significant, $p = .767$. Adding BFEA participation to the model did not change its significance, and BFEA participation was not a significant predictor, $t(437) = -.02$, p = .988. This indicates that the sense of belonging for the student sample as a whole, regardless of BFEA participation, was tied to first-semester math performance.

A separate regression analysis was performed for BFEA students, and results were similar to the cohort model, $F(2, 42) = 3.69$, $p = .033$, $R^2 = .15$. The standardized beta value describing the linear effect of math performance on change in sense of belonging was similar to the cohort model: $t(42) = -2.58$, $p < .013$, $B = -.37$, and again, math course was not a significant predictor, $p = .213$. The similarity between the cohort and the BFEA regression results indicates that the BFEA population did not differ from the student cohort with respect to how much math performance impacted their sense of belonging.

Again, one interpretation of these results is that BFEA had no effect on belonging and resilience. Some research has shown that individual characteristics such as student maturity affect how much students benefit from SBPs [16], which may have occurred in our BFEA population. Other factors like the relatively short length of the program (2 weeks instead of 3 or 4 weeks), the testing paradigm within the math preparation, or something else about the design of the program did not successfully impact students' sense of belonging.

However, it is also possible that BFEA participants started the program with a lower sense of belonging in engineering. The program could have then raised and/or reinforced students' sense of belonging such that it met the level of the cohort as a whole by the start of the first semester. As it is not possible to differentiate between these interpretations with our current dataset, future work is needed to determine the impact of BFEA on students' sense of belonging. For example, we could collect data with a pre- and post-survey, before and after the program. This approach would directly assess the impact of the SBP on belonging, and better contextualize our current findings. The fact that we do not see a deficit in belonging in this sample of URM students is promising for future research.

C. Limitations

This study was conducted at one university, making the generalizability of the results unclear. In addition, although the dataset included two consecutive years, separate analyses were not conducted due to sample size limitations. It is possible that results differed across years.

More importantly, this study was performed retrospectively, and did not directly test whether BFEA improved students' sense of belonging. More work is needed to understand the potential benefits of SBPs with respect to incoming URM students' sense of belonging.

V. Conclusions & Future Work

Preliminary findings indicate that students who had attended BFEA, a summer bridge program at the University of Louisville, have equivalent levels of belonging in engineering to the general student population at the beginning of a fall semester. In addition, both BFEA participants and the cohort as a whole had similar changes in sense of belonging due to math performance, where lower math performance resulted in a negative change in belonging. Due to the differences in student samples, it is still possible that BFEA impacts belonging by mitigating deficits that exist before the program. Further investigation is warranted to fully comprehend the impact of BFEA for the targeted student population.

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