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Evaluating the five pillars of a Summer Bridge Program and their influence on participants' intentions to complete an engineering degree.

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Abstract

In the United States, increasing enrollment and retention in engineering degrees remains an ongoing challenge in higher education. Moreover, current university educational efforts aim to increase the immediate enrollment of diverse students right after high school completion. Early educational programs like Summer Bridge aim to enhance academic preparation, goal achievement, and persistence in students before their first academic semester, ensuring academic success and persistence in engineering in the early stages of college life. Even though Summer Bridge Programs (SBP) are well known across higher institutions, our long-running summer bridge program contributes an important perspective to the discussion about the impact of summer bridge programs on underrepresented minority students (URM). At Mississippi State University, the SBP that has been implemented for more than 25 years provides targeted support to URM engineering students, and by far majority of the participants are URMs. However, a strategic partnership has recently been implemented that provides cooperation between the university and industry sponsors. Therefore, this paper aims to evaluate the effectiveness of the new SBP structure at MSU in enhancing college success for incoming engineering students. This paper provides an overview of the five pillars of the program (academics, bonding, engineering at MSU, engineering projects, and industry), their goals, expected outcomes, and ways to assess their contribution to the retention of URM students, with a special focus on Black engineering students as they represent the majority of participation in our program. By conducting pre- and post-student surveys with the 35 participants in the 2024 cohort, we investigated how participation in the summer bridge program affects academic readiness, self-efficacy levels, goal orientation, expectations, and sense of belonging among participants and ultimately their intentions to pursue or not pursue an engineering major. Subscales included self-efficacy (general, design, and experimental), the Achievement Goal Questionnaire (AGQ), and items from the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) were applied. Participation in SBP showed statistically significant differences in items that measured self-efficacy, academic readiness, sense of belonging, and knowledge about university life and industry. However, goal orientation and career expectations did not exhibit changes. Results support that the current five-pillar structure effectively promotes student success and persistence in engineering degrees for first-year students at Mississippi State University.

Introduction

In the United States, educational efforts aim to increase enrollment in 2- or 4-year institutions right after high school completion, known as the immediate college rate [1, p. 24]. Specifically, increasing enrollment and retention in STEM degrees remains an ongoing challenge as its workforce accounts for 24% of the total U.S. workforce [2]. In this regard, there is a special interest in increasing the number of degrees in STEM, but also in the fact that workers represent the diversity of the country. In order to promote STEM degrees, it is important to work alongside academia to maintain a steady professional flow and achieve diversity goals, as underrepresented professionals just accounted for 23% of STEM workforce in 2021, compared to 31% of the US employment in Non-Stem fields. [2]. Thus, efforts to increase academic preparation for underrepresented minorities (URM) are pivotal to increasing diversity in the U.S. STEM community.

Educational research on this matter indicates that URM students' enrollment rates are similar to those of white students. Nonetheless, there are significant differences in the persistence rates of minority students in STEM disciplines [3]. This disparity is attributed to different factors, such as financial support, academic load, or institutional engagement, that contribute to the gap between URM students and their white peers [4], [5]. Statistical data for 2024 showed that approximately 18% of bachelor's degrees in science and engineering are awarded to Hispanic students, 9% to African American students, and just 0.4% to American Indian or Alaska Natives. This means that despite current efforts, academic institutions are far from achieving equity at professional levels.

To ensure academic success and persistence for URM students in STEM, it is important to develop early educational programs that prepare students to navigate successfully college life. One of these initiatives is the Summer Bridge Programs (SBP), which focus on increasing academic preparation, achievement, and persistence in students prior to their first academic semester [6]. Moreover, SBP programs help increase the retention of diverse students as their structure promotes collaborative, inclusive, and self-efficacious learning environments, consequently contributing to improving innovation through increased diversity in higher institutions [7].

The summer Bridge program at Mississippi State University seeks to improve college readiness for incoming engineering first-year students. The recruitment practices are targeted towards URM students but admission to the program is not limited only to URM students. The program aims to support student growth in academics, community, and life skills as they transition from high school to university. Through experiences in academics, hands-on learning, and life skills, students can experience the connection between academy and professional practice and feel motivated to pursue an engineering degree. The program was established in 1995, and since then it has significantly contributed to promoting diversity in the Bagley College of Engineering as participants come from diverse backgrounds with an important representation of African-American communities as shown by a recent analysis of outcomes for Black students who participated in the program from 2012 to 2021 [8]. Compared to similar students who did not participate, summer bridge students had significantly higher first semester GPA (2.97 versus 2.79), were 19% more likely to pass calculus 1, and were 15% more likely to earn a degree and 52% more likely to graduate with an engineering degree [8]. In total 333 students have participated since 2012-2024, with 30% first-generation college students and 90% from African American communities [9], [10].

Even though the program has been offered for more than twenty years, its structure has changed over time. Currently, the program uses a project-driven approach with a strong involvement of the industry sponsor. The objective of this approach is to allow participants to interact with practitioner engineers and connect the learning experiences on campus with fundamental engineering concepts that they will apply to complete their final projects. To accomplish a holistic program the current structure is founded in five pillars: Bonding, Academics, Engineering at MSU, Engineering project, and Engineering Industry. In this regard, the present study aimed to develop the learning outcomes for the current program structure and assess its effectiveness by identifying the differences in self-efficacy levels, math outcome expectations, goal orientation, feeling of inclusion, knowledge about MSU, the engineering industry, and career success expectations for the 35 bridge participants 2024 in an attempt to understand the driving factors that influence college success and persistence in engineering degrees.

Overview of the five pillars of the program

SBP structure at Mississippi State University provides learning experiences that help students start with strong foundations and tools to navigate the engineering curriculums, and is based on five pillars. Each pillar is designed to enhance the accomplishment of learning outcomes[10]. The purpose and goal for each pillar of the program are summarized as follows:

Bonding: The program provides experiences where students can relate to each other and build a support group. The goal of the pillar is to provide spaces for students to connect and offer support through the program and beyond.

Academics: The program offers academic courses in mathematics, chemistry, and programming to prepare engineering students in academics to ensure success in the the fall semester. The mathematics placement is based on individual ACT scores among college algebra, pre-calculus, and calculus I. The mathematics courses are offered with credits, allowing students to advance in their curriculum.

Engineering at MSU: The program offers learning experiences in laboratories and research centers to enlighten students with the many opportunities offered by the institution for student development and success. This pillar aims to allow students to make the connection between the course and lab material and their potential applications as engineers.

Engineering Project: This pillar offers hands-on learning experiences where students apply theoretical concepts in real scenarios and have a first-time experience applying engineering knowledge. The goal of this pillar is to apply the acquired knowledge from courses and labs to a real engineering project designed by faculty and industry sponsors.

Engineering Industry: This pillar provides experiences with engineers and their duties in the industry. Industry trips give the chance to students to be exposed to how engineering works and the differences among engineering disciplines. This pillar seeks to promote engagement between academia and industry.

Summer Bridge Learning Outcomes

The program learning outcomes were created based on Bloom's taxonomy, which establishes that learning outcomes should describe the actions students should accomplish after the educational experience. Bloom’s taxonomy is organized in a hierarchical structure where each category contains subcategories that are dependent on having accomplished the action at the lower levels [11]. Therefore, the summer bridge activities learning outcomes focus on building foundational knowledge and skills that help first-year students navigate their engineering degrees. Figure 1 lists the four learning outcomes that covered the purpose of the five pillars and they are proposed to provide a starting point to assess the program's effectiveness in light of these outcomes.

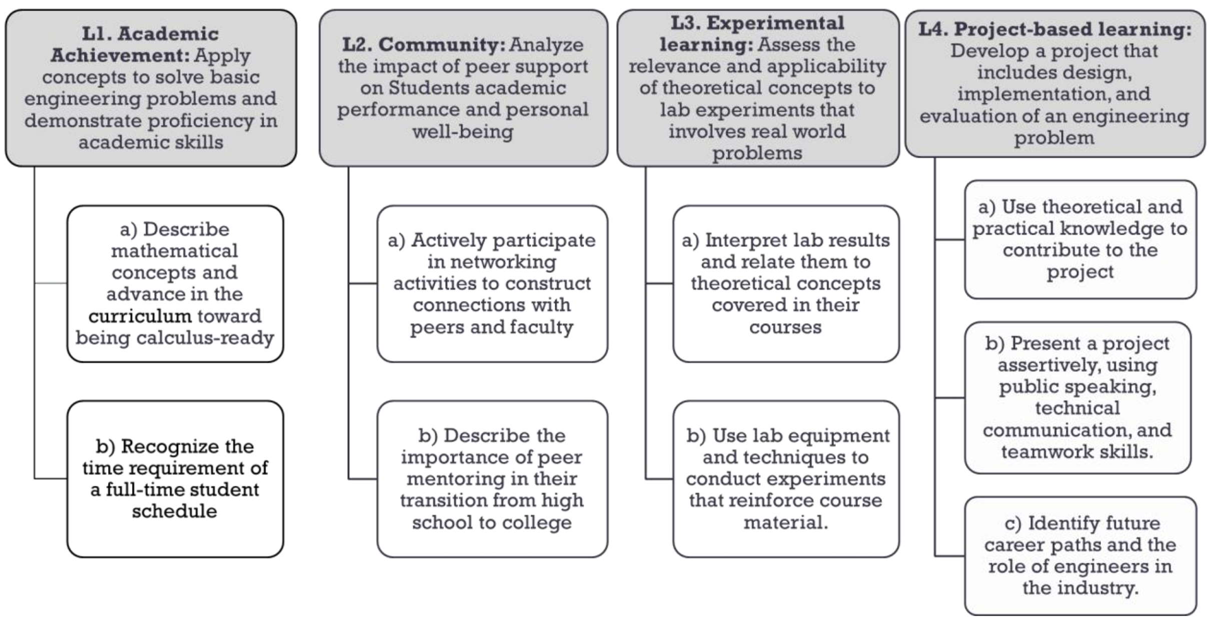

Figure 1. *Summer Bridge Program Learning Outcomes.*

Assessment of five pillars and learning outcomes.

A pre and post-student survey was designed to compare learning progress from students' measures to assess the achievement of the established learning outcomes. The structure of the survey ensured the linkage between the questions, activities from the five pillars, and learning outcomes that help to determine academic readiness, self-efficacy levels (general, design, and experimental), expectations, sense of belonging, and ultimately their intentions to pursue or not pursue an engineering major.

Self-Efficacy in Engineering

Self-efficacy is understood as how well students feel motivated and take the necessary action to handle potential scenarios based on their beliefs about their own efficacy [12]. For the purpose of the study, the interest is to understand if participants feel confident in performing well in academics, experiments, and engineering design[13]. These approaches reflect how the learning experiences contained in each pillar of the program might influence participants' belief in succeeding in engineering curriculums.

Goal Orientation

Achievement goal theories study individual motivation to engage or not in educational tasks. This can be measured either by personal improvement (mastery) or by comparing oneself to others (performance). When goal achievement focuses on mastery, the purpose is to gain new skills, while focus on performance aims to do well compared to others. Additionally, students can focus on s on achieving positive outcomes (success) or avoiding negative outcomes (failure) [14]. By combining these concepts, there are four types of achievement goals.

- **Mastery-Approach:** Focused on achieving personal growth or mastering a task.
- **Performance-Approach:** Focused on being better than others and gaining recognition.
- **Mastery-Avoidance:** Focused on avoiding misunderstanding or failing to learn.
- **Performance-Avoidance:** Focused on not being seen as worse than others.

Feeling of inclusion

A sense of inclusion refers to student’s perceptions of acceptance by others. However, underrepresented students face additional challenges in developing a sense of inclusion when stereotypes suggest that they may not fit well in certain environments, such as engineering academic courses [15]. Therefore, understanding how the learning experiences provided for the summer Bridge program develop a greater sense of belonging in engineering degrees is important to ensure student success.

Engineering career success expectations

One important factor of persistence in an engineering degree is to properly align the expectations related to future roles and the way academia will contribute to achieve professional goals. In other words, measuring career expectations will disclose how the SBP influences motivations for students to reaffirm their decision to pursue engineering majors.

Knowledge of engineering at MSU.

The transition from high school to college is inherently challenging, as access to resources increasingly relies on students' independence and self-regulation. Consequently, first-year students' understanding of the institutional structure, along with their awareness of opportunities for engagement in extracurricular activities, such as research initiatives, cooperative education (co-op) programs, and student organizations, plays a critical role in influencing their overall success at MSU.

Knowledge of Industry.

Engineering degrees are centered around problem-solving and applicability. It is important to understand the perception of students about the industry and how participation in SBP helps to align their expectations about career paths and future roles in engineering after college graduation.

Purpose of the Study

Given the necessity to have effective intervention programs such as Summer Bridge that promote URM participation in the STEM field, the study addresses the following research question:

1) Does participation in the summer bridge program significantly increase a) self-efficacy, b) math outcome expectations, c) goal orientation, d) feeling of inclusion, e) knowledge of MSU and the engineering industry, and f) career success expectations among students?

The current study hypothesized that participation in the SBP will positively influence students' self-efficacy levels, math outcome expectations, goal orientation, feeling of inclusion, knowledge about MSU and the engineering industry, and career success expectations.

Method

Participants

The study participants were 35 incoming engineering students (n = 35) who participated in the 2024 summer bridge program at Mississippi State University. Participants were enrolled in various engineering disciplines (e.g., chemical, computer, mechanical, and civil); for all of them, it was their first-time experiencing college life in a post-secondary institution. Additional demographic information can be found in Table 1

Table 1

Demographic Information for Participants in the Study.

Category	Sample	
	n	%
Gender		
Female	10	29
Male	25	71
Race/Ethnicity		
White	6	17.1
Black or African American	27	77.1
Hispanic or Latino	1	2.9
Asian	1	2.9
Major		
Mechanical Engineering	8	22.9
Computer Science	2	5.7
Aerospace Engineering	2	5.7
Biomedical Engineering	8	22.9
Electrical Engineering	5	14.3
Civil Engineering	1	2.9
Computer Engineering	3	8.6
Industrial Engineering	1	2.9
Biosystems Engineering	1	2.9

Petroleum Engineering	1	2.9
Chemical Engineering	2	5.7
Cybersecurity	1	2.9

Note. N = 35 Participants were on average 18.0 years old

Procedure

A cross-sectional survey was administered to students on paper using a 7-point Likert-type scale ranging from 0 (Strongly Disagree) to 6 (Strongly Agree). The survey respondents' perceptions about coursework, skill development, and academic improvements. Questions were structured based on subscale items used to measure self-efficacy, math outcome expectations, sense of inclusion, and career expectation outcomes.

Instrument Measures

The instrument is divided into ten separate subscales, seven of them have been used in the literature as they are reliable for evaluating engineering students and two of them are developed based on knowledge that students are expected to gain from the SBP about university life and industry.

General Self-efficacy: Self-efficacy was assessed using the Self-Efficacy for Academic Achievement scale, adapted from the context of engineering [13]. The scale items measure students' perceived capability to grasp academic content in the summer bridge coursework.

Engineering self-efficacy II: Longitudinal Assessment of Engineering Self-Efficacy (LAESE) subscale that measures participants’ confidence in succeeding in the engineering curriculum [16].

Design Self-Efficacy: It measured the participants’ confidence to develop a design and apply it to solve problems [17].

Experimental Self-Efficacy: Students' perceived comfort in engaging in experimental activities [17].

Knowledge about Engineering at MSU: Students' understanding of university life and what it means to be a student in the College of Engineering.

Knowledge about the Engineering Industry: students' understanding of the working environment and their ability to effectively allocate resources for practical work while navigating their engineering curricula.

Math outcome expectation: LAESE subscale that measures students’ expectation that they doing well in mathematics courses will help the to succeed in engineering [16].

Feeling of inclusion: LAESE subscale that measures the perception that a participant shares significant similarities with their peers [16].

Achievement goals: A revised achievement Goal Questionnaire (ACG) to assess achievement goal items. In total 12 items represent a 2 X 2 model. Participants responses were averaged to obtain mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance indexes [14].

Engineering career success expectations: LAESE subscale that measures the participant's perception of the benefits of pursuing an engineering degree [16].

The subscales were used to understand changes in those items for students after they participated in the SBP at MSU. Table *2* presents the alignment among the program's foundational pillars, learning outcomes, and assessment tools. The purpose of this alignment is to correlate the survey results with the established learning experiences and based on the results verify their effectiveness or identify areas of improvement for future versions of the program.

Table 2.

Assessment methods for the Summer Bridge Program structure and learning outcomes.

Pillar	Learning Outcome	Assessment tool
Academics	L1. Academic Achievement	General engineering self-efficacy Engineering self-efficacy II Math outcome expectations Goal Orientation
Bonding	L2. Community	Feeling of inclusion
Engineering at MSU	L3. Experimental learning	Knowledge about Engineering at MSU Experimental self-efficacy
Project Industry	L4. Project-based learning	Design Self-Efficacy Knowledge about Industry Engineering career success expectations

Analysis

Exploratory descriptive statistics for the subscales were examined for the two experimental conditions, which included means, standard deviations, outliers, skewness, and kurtosis coefficients using IBM SPSS Statistics version 29.0. Outliers were identified and removed by applying the Interquartile (IQR) method [18], which removes straightlining responses where a participant marked nearly identical answers for all questions, reducing data quality. This behavior was observed when the survey was completed quicker than a participant could read the questions, reflecting a lack of engagement with the questions. An analysis of variance was performed to determine if there are significant differences among self-efficacy, math outcome expectations, goal orientation, feeling of inclusion, engineering at MSU, knowledge of the industry, and career success expectations after participation in the program. To be able to apply a parametric statistical test (t-test) to the SBP sample, the data were tested with the Kolmogorov-Smirnov and the Shapiro-Wilk tests to verify whether the data meets the statistical test assumptions of normality and independence or not [19].

Results

After removing outliers, the mean values for the analyzed subscales met the assumption of normality and independence according to the Kolmogorov-Smirnov, and the Shapiro-Wilk tests. In both the pre and post-conditions. Each parameter for both scenarios exhibited a high score (greater than 4.0), and the z score of skewness and kurtosis were greater than -1.96 and less than 1.96 corresponding to normal distributions (Table 3 and 4).

Table 3

Descriptive statistics for the Pre-condition.

Variable	Mean	Standard Deviation	Range		Skew	Kurtosis
			Min.	Max.		
General engineering self-efficacy	4.72	0.50	3.67	5.67	-0.38	0.20
Engineering self-efficacy II	4.57	0.61	3.00	6.00	0.00	0.74
Math outcome expectations	4.58	0.99	2.00	6.00	-0.69	0.23
Goal Orientation						
Mastery-approach goals	5.37	0.62	4.00	6.00	-0.76	-0.43
Mastery-avoidance goals	4.62	1.16	2.00	6.00	-0.82	0.02
Performance-approach goals	4.53	1.10	2.33	6.00	-0.36	-0.82
Performance-avoidance goals	4.75	0.93	3.00	6.00	-0.24	-0.80
Feeling of inclusion	3.76	1.05	1.40	6.00	-0.41	0.21
Engineering at MSU	4.55	0.69	3.00	6.00	-0.08	-0.38
Experimental Self-Efficacy	4.49	0.72	2.60	6.00	-0.30	0.69
Design Self-Efficacy	4.43	0.46	3.43	5.74	0.16	1.36
Engineering Industry	4.30	0.78	2.60	5.60	-0.62	-0.14
Engineering career success expectations	5.09	0.55	3.88	6.00	-0.14	-0.50

Table 4

Descriptive statistics for the Post-condition.

Variable	Mean	Standard Deviation	Range		Skew	Kurtosis
			Min.	Max.		
General engineering self-efficacy	5.15	0.46	4.33	6.00	0.31	-0.49
Engineering self-efficacy II	4.68	0.73	2.83	6.00	-0.52	0.46
Math outcome expectations	5.05	0.74	3.67	6.00	-0.34	-1.17
Goal Orientation						
Mastery-approach goals	5.51	0.51	4.33	6.00	-0.79	-0.25
Mastery-avoidance goals	5.09	0.74	3.00	6.00	-0.93	0.98
Performance-approach goals	4.77	1.10	2.67	6.00	-0.51	-0.88
Performance-avoidance goals	4.95	0.99	2.33	6.00	-0.82	0.13
Feeling of inclusion	4.56	1.10	2.00	6.00	-0.77	-0.15
Design Self-Efficacy	4.77	0.70	3.00	6.00	-0.25	-0.08

Engineering at MSU	4.96	0.61	3.67	6.00	-0.09	-0.16
Experimental Self-Efficacy	4.85	0.61	3.40	6.00	-0.47	0.50
Industry	4.77	0.59	3.40	6.00	-0.28	-0.08
Engineering career success expectations	5.08	0.66	3.50	6.00	-0.58	-0.47

Pearson correlations were also determined among the pre- and post-conditions, and as expected for repeated, measures subscales were significantly correlated with a range from 0.4 to 0.78 with a bootstrap confidence interval, BCa 95% CI [-0.0005,0.88]. Table 5 illustrates that participation in the summer bridge program increased all subscales scores, except the engineering success career expectations. The comparison between the pre-and post-conditions was significant for the general engineering self-efficacy, design self-efficacy experimental self-efficacy, math outcome expectations, feeling of inclusion, and engineering at MSU subscales and represented a medium effect size ($d \approx 0.5$). While the engineering industry mean difference was also significant $t(33) = -4.76$, $p < .001$, but represented a large effect size (d=-0.82). On the other hand, although the means for engineering self-efficacy II, goal orientation items, and engineering career success expectations differ in the two scenarios, those were not statistically significant (Table *5*).

Table 5

Repeated measures t-tests of subscale scores between pre (mean 1) and post (mean 2) conditions.

Variable	df	Mean 1	Mean 2	Mean difference	t-statistic	Cohen's d
General engineering self-efficacy	31	4.7	5.1	0.433	-4.22***	-0.75
Engineering self-efficacy II	34	4.6	4.7	0.110	-1.12	-0.19
Math outcome expectations	33	4.6	5.0	0.468	-3.05**	-0.52
Goal Orientation						
Mastery-approach goals	32	5.4	5.5	0.134	-1.32	-0.23
Mastery-avoidance goals	28	4.6	5.1	0.470	-1.76	-0.33
Performance-approach goals	32	4.5	4.8	0.239	-1.66	-0.29
Performance-avoidance goals	29	4.7	4.9	0.199	-1.51	-0.28
Feeling of inclusion	33	3.8	4.6	0.797	-3.72***	-0.64
Design Self-Efficacy	34	4.4	4.8	0.333	-3.46**	-0.58
Engineering at MSU	34	4.5	5.0	0.411	-4.29***	-0.73
Experimental Self-Efficacy	34	4.5	4.9	0.356	-3.07**	-0.52
Engineering Industry	33	4.3	4.8	0.479	-4.76***	-0.82
Engineering career success expectations	34	5.1	5.1	-0.004	0.05	0.01

*p < .05. **p < .01. ***p < .001

Discussion

Overall, correlation analysis demonstrated that the items on the studied subscales were positively correlated across both scenarios. This outcome aligns with the experimental design, as data for both scenarios were collected from the same participants before and after their participation in the SBP. Furthermore, the findings indicate that participation in the SBP is associated with increased levels of general engineering self-efficacy, design self-efficacy, experimental self-efficacy, math outcome expectations, a sense of inclusion, and knowledge of both engineering at MSU and within the engineering industry. The robust bootstrap confidence intervals (BCa 95%) confirmed that the true value of the mean difference for all subscale items was captured within these intervals. Furthermore, in cases where subscales exhibited statistically significant differences, the BCa confidence intervals were negative, not including zero. This suggests that the mean difference is unlikely to be zero, thereby providing sufficient evidence to reject the null hypothesis for those subscales. In other words, the perception of participants about their skills was statistically different in the post-program scenario (Table 5).

Learning experiences designed in the Academics, Engineering at MSU, and Project pillars of SBP produced differences in general self-efficacy, design self-efficacy, and experimental self-efficacy between the initial conditions of the students and the conditions after participating in the summer program. It has been shown that students with higher self-efficacy levels may perform well academically and persist in engineering degrees [12], [20]. Regarding math outcome expectations increasing expectations of doing well in mathematics will promote interest in engineering courses and motivate students to achieve goals and actions in pursuit of engineering careers [21]. Consequently, the findings of this study suggest that the current structure of the SBP enhances the academic readiness and success of incoming engineering students (Learning outcome 1. Academic Achievement).

Additionally, the summer bridge program increased the sense of inclusion among participants comparing how they felt in their high schools and in the SBP. One important factor that challenges the persistence of URM students in engineering degrees is developing a sense of belonging in the institution and the engineering field [15]. Therefore, providing a friendly institutional environment will be pivotal to promoting a strong sense of inclusion for URM students (Learning outcome 2. Community). Ultimately, knowledge about the roles of engineers in the industry had a statistical significant difference and a large effect size for the differences between means for the two conditions (Table 5, $p<.001$). The results suggest that participating in the summer bridge program, especially in the industry pillar positively changes their perceptions of the practice of engineering and the future career paths they can pursue once they finish their degrees (Learning outcome 4.c Project-based learning).

In contrast, although differences were observed in engineering self-efficacy II, goal orientation, and engineering career success expectations between the two scenarios, these differences did not reach statistical significance. This lack of significant change may be attributed to the fact that these subscales correspond more to deep individual beliefs about success in achievement settings that are difficult to change in a short program such as SBP. Nonetheless, the findings of this study suggest that participation in the program can help students redefine their conceptions of success and adopt new approaches for evaluating personal progress and career expectations. Consequently, there is an opportunity to strengthen activities in future versions of the program that support setting achievable goals and career expectations after completing an engineering degree at MSU. Overall, this study supports the hypothesis that the learning activities encompassed within the five pillars and learning outcomes implemented at MSU have a positive influence on students' self-efficacy, expectations, and sense of inclusion, thereby contributing to the retention of underrepresented minority students in engineering disciplines.

Limitations and Recommendations for Future Research

A significant limitation of this study is the absence of controlled variables, such as ACT mathematics scores, gender, race, Pell Grant eligibility, and first-generation college status, which are critical indicators of academic success in the first semester. The main reason for not controlling these parameters was that the study's main focus was to understand if summer bridge participants were achieving the learning outcomes according to the five-pillar structure. However, future research should address these limitations by including bigger samples across years where academic achievement and performance can be disaggregated by groups.

Conclusions

In conclusion, this study provides evidence supporting the effectiveness of the current project-driven structure at MSU in enhancing college readiness among participants of the SBP. The findings indicate that participation in the Summer Bridge Program positively impacts self-efficacy in engineering, math outcome expectations, a sense of inclusion, and knowledge of engineering at MSU and within the industry, as these subscales demonstrated statistical significance and considerable effect sizes when comparing the pre and post scenarios. Although the results for the goal orientation and career success expectation subscales did not achieve statistical significance, they highlight an opportunity to further enhance learning experiences that foster academic readiness, student success, and career aspirations for incoming engineering students. Overall, based on the results of the current study the implementation of the five-pillar structure suggests to be effective in promoting persistence and success within engineering disciplines at MSU.

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