Aligning Program Goals with Outcomes: An Evidence-Based Study of an Engineering Bridge Program

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Abstract

Evidence-Based Practice Research Brief Paper. Persistent challenges in first-year retention among engineering students underscore the need for intentional interventions that support academic, social, and professional transitions from high school to college. Summer Bridge Programs (SBPs) are well-established early interventions designed to ease this transition by preparing students academically and addressing the environmental and social factors that can jeopardize persistence in engineering. While SBPs have demonstrated positive outcomes across institutions varying in length, target population, and structure. Many evaluations assess general student gains without explicitly aligning program goals with measured student outcomes.
This study examines the effectiveness of a five-pillar Summer Bridge Program (SBP) at a large public university in the southeastern United States. The program is structured around five pillars: academic readiness, student bonding, hands-on learning, project-based learning, and career development, each aligned with specific learning outcomes that support holistic students' growth beyond the classroom. Grounded in the Model of Co-Curricular Support (MCCS), this study investigates how participation in the SBP influences three primary constructs associated with student success: self-efficacy, sense of belonging, and career development.
A pretest–posttest quasi-experimental design was employed with 91 first-year engineering participants from two cohorts of the SBP. Students completed validated subscales aligned with program goals to measure educational constructs before and after the intervention. Data were analyzed using Repeated Measures Analysis of Covariance (RM-ANCOVA), with ACT Math scores as a covariate, to examine within-group changes across constructs. Results indicate a large and statistically significant improvement in students' sense of inclusion, as well as a significant increase in institutional awareness, reflecting strengthened social integration and familiarity with institutional resources. Academic and professional development constructs demonstrated positive but more modest gains. These findings contribute to the evidence base for SBPs by demonstrating the value of aligning program design and assessment with a theoretical co-curricular framework. The study highlights which program components may drive the strongest student gains and offers a transferable assessment approach for improving early engineering interventions.

Keywords: First Year Experience, Co-curricular, Student Assessment, Alignment

Introduction

Higher education goals strive to promote enrollment in bachelor's degrees following high school graduation, a metric referred to as the immediate college rate [1]. While increasing enrollment is an important goal, the following challenge lies in supporting student persistence and degree completion, particularly in engineering education, where first-year attrition rates remain high and the first two years represent a critical threshold for student departure [2], [3]. The transition from high school to college presents academic, social, and emotional challenges that can jeopardize student success, particularly for students from underprepared backgrounds [4], [5]. To address these challenges, institutions have implemented early intervention strategies such as Summer Bridge Programs (SBPs), which aim to support incoming engineering students in adjusting to college life [6]. However, although SBPs are widely used, there is still limited understanding of how specific program elements contribute to student outcomes [7], [8]. This study addresses these limitations by examining a Summer Bridge Program intentionally designed and evaluated using the Model of Co-Curricular Support (MCCS) [9]. The MCCS highlights how structured co-curricular experiences foster academic integration, peer interaction, faculty engagement, and career development within engineering pathways, offering a theoretical lens to better understand how SBPs influence multiple domains of early engineering student success.

Relevant Literature

Co-curricular support refers to institutionally led initiatives that complement the academic curriculum and promote students' academic, social, and personal development [9], [10]. For engineering students, this often takes the form of mentoring, tutoring, and orientation activities. Summer Bridge programs in engineering education are early interventions designed to prepare incoming first-year engineering students academically while fostering early social integration [11], [12]. Prior research demonstrates that SBPs can strengthen academic preparedness, increase engineering self-efficacy, and improve first-year retention in engineering programs [11], [13]. Beyond academic benefits, SBPs also support students' social integration through cohort-based structures that encourage peer bonding, collaboration, and community building [12].

Despite these positive outcomes, less is known about which specific SBP components, such as, academic preparation, peer interaction, hands-on engineering experiences, or professional exposure, are most influential in shaping student success [14]. Many evaluations rely on broad indicators like GPA or persistence and do not align program activities with measurable learning outcomes. Additionally, few studies use validated quantitative instruments that allow for systematic pre–post assessment framed in established theories of student support and development [15]. This leaves a gap in understanding how SBPs influence distinct domains of early engineering student success and which program features yield the greatest benefits.

A central goal of SBPs is to strengthen academic self-efficacy, students' beliefs in their ability to succeed in engineering coursework and complete engineering-related tasks [15]. Self-efficacy, grounded in Bandura's social cognitive theory, reflects individuals' perceptions of their competence and their expectations of successful outcomes [16]. Research shows that higher levels of self-efficacy contribute to stronger coping mechanisms, greater academic persistence, and improved performance in engineering contexts [17].Thus, assessing changes in self-efficacy provides insight into students' academic readiness as they enter their first semester.

Another common SBP objective is to enhance students' sense of belonging, which encompasses feelings of acceptance, value, and connectedness within the college community staff [18], [19]. In SBP settings, structured peer interaction and early exposure to campus life have been shown to strengthen belonging and help students acclimate to the engineering environment [20]. Because belonging is strongly associated with persistence and retention in STEM, it is a critical construct to measure when evaluating SBP effectiveness.

To guide this study, the Model of Co-Curricular Support (MCCS) is applied as the theoretical framework [9]. MCCS builds on and extends Tinto's (1993) theory of student departure, shifting the focus from institutional-level engagement [21] to the departmental and programmatic experiences that shape engineering student success [10], [22]. While other theoretical frameworks contribute to understanding student persistence and retention, they often focus on isolated aspects of the undergraduate experience across disciplines and do not explicitly distinguish between curricular and co-curricular support within engineering education [23]. In contrast, MCCS provides a more specific lens by conceptualizing co-curricular interventions as experience-based "tools" that support students' academic, social, and professional development. This perspective enables researchers to examine how specific program elements, rather than programs as a whole, contribute to student development and degree progress.

Methodology

Research Design

This study employed a quasi-experimental pretest–posttest design without a control group to evaluate the effectiveness of a Summer Bridge Program (SBP) for incoming engineering students. The program duration is five weeks, and it is structured around five pillars: academic readiness, peer bonding, hands-on learning, project-based experiences, and industry exposure. Because participants were already enrolled in the program through institutional selection processes, random assignment was not feasible. Therefore, a within-subjects design was appropriate for examining changes in key student outcomes over time. This design aligns with the study's goal of assessing how participation in an SBP influences constructs associated with early engineering success while grounding program evaluation in the Model of Co-Curricular Support (MCCS) theory and its domain: academic performance, peer-group interactions, faculty interaction, and professional development [22].

Participants and Sampling

Participants consisted of two cohorts ($n = 91$) of first-year engineering students enrolled in a five-week SBP at a large public research university in the southeastern United States. A purposive sampling strategy was used because SBP participation is based on institutional invitation, which considers students' declared engineering major, ACT Math score, and indicators of academic readiness. This sampling approach reflects the program's mission to support students who may benefit from additional academic and social preparation prior to enrolling in first-semester engineering courses.

Instrumentation

Data was collected using a structured survey composed of validated subscales selected to align with SBP learning outcomes and the domains of the Model of Co-Curricular Support (MCCS). All items used a 7-point Likert-type response scale ranging from 0 ("strongly disagree") to 6 ("strongly agree"), with higher scores indicating stronger perceived competence, belonging, or preparedness depending on the construct measured. The following sets of instruments were administered:

1. **General Engineering Self-Efficacy**
   Adapted from Mamaril et al. (2016), these subscales measure students' confidence in engaging with engineering content and performing engineering-related tasks (e.g., "I can understand complex engineering concepts") [24]. (6 items)

2. **Sense of Belonging and Inclusion**
   Derived from the Rescaling the Longitudinal Assessment of Engineering Self-Efficacy V3.0 for Undergraduate Engineering Students and the Postsecondary Student Engagement (PosSE) Survey [25], [26]. These subscales capture peer interaction, feelings of inclusion, and academic belonging, measuring the perception of sharing significant similarities with their peers, acceptance, fit, and inclusion. (4 items per subscale).
3. **Institutional Awareness**
   Items assess students' understanding of campus life, expectations, and available academic support resources (6 items).
4. **Career Development and Engineering Perceptions**
   These subscales measure students' perceptions of engineering practice, industry awareness, and expectations for professional success [26] (6 items each).

Higher scores represent stronger perceived readiness or integration within the relevant MCCS domain. Reliability evidence from prior studies reports high internal consistency ($\alpha \geq .80$) for all.

Data Analysis

The primary analysis used RM-ANCOVA to examine within-group changes from pre- to post-program across all constructs while controlling for ACT Math scores as a covariate. This method compares subscales measured at two points (pre and post) while controlling for a covariate that may influence the outcomes. Therefore, results isolate SBP-related change by adjusting for prior academic preparation. Partial eta-squared was used to estimate effect sizes. Normality, homogeneity of variances, and homogeneity of regression slopes were evaluated prior to conducting inferential tests. The assumption of sphericity was not applicable because only two time points were included.

Results

After analyzing the data in SPSS Software, assumptions of homogeneity of regression slopes were satisfied for all constructs, indicating that the relationship between the covariate and dependent variables did not differ across time points. The Shapiro-Wilk test indicated that most of the measures violated the assumption of normality ($p < 0.05$). However, visual inspection of Q-Q plots revealed that the data points closely followed the diagonal reference line, indicating only minor deviations. RM-ANCOVA is considered robust to such violations, given the sample size (n=91) [27]. Therefore, parametric procedures can be applied to the data. The results are presented in the following table.

Table 1. Repeated Measures ANCOVA Results by MCCS Domain

Construct	Pre Mean (SE)	Post Mean (SE)	Δ Mean	F (Time)	p (corrected)	Partial η^2
Academic Support						
General Engineering Self-Efficacy	4.66 (0.08)	4.93 (0.07)	+0.28	0.03	0.85	< .001
Math Expectations	4.66 (0.09)	5.06 (0.08)	+0.4	2.88	0.09	0.03

Peer-Group Interaction						
Peer Interaction	3.28 (0.16)	3.73 (0.20)	+0.45	0.84	0.36	0.02
Inclusion	3.98 (0.11)	4.49 (0.15)	+0.51	78.29	< .001	0.47
Faculty/Staff Interaction & Extracurricular Involvement						
Academic Belonging	3.71 (0.17)	4.39 (0.23)	+0.68	0.01	0.93	< .001
Institutional Knowledge	4.47 (0.07)	4.96 (0.08)	+0.5	7.94	0.01	0.08
Professional Development						
Industry Knowledge	4.29 (0.08)	4.78 (0.08)	+0.49	1.67	0.20	0.02
Career Expectations	5.05 (0.06)	5.08 (0.07)	+0.03	0.00	0.99	< .001

Note: Standard errors are shown in parentheses. Partial eta squared (η^2) represents effect size, with values of .01, .06, and .14 indicating small, medium, and large effects, respectively.

Results from the RM-ANCOVA analyses revealed gains across MCCS domains. Within the academic support domain, general engineering self-efficacy and math expectations showed small positive increases from pre- to post-program; however, these changes were not statistically significant after controlling for ACT Math, indicating modest improvements in academic confidence. The strongest improvements emerged in the peer-group interaction domain. While peer interaction showed positive but nonsignificant gains**,** students' sense of inclusion increased significantly, $F(1, 89) = 78.29$, $p < .001$, partial $\eta^2 = .47$, representing a large effect. In the institutional integration domain, students' institutional knowledge also increased significantly, $F(1, 89) = 7.94$, $p = .01$, partial $\eta^2 = .08$. Finally, in the professional development domain, industry knowledge and career expectations showed positive directional trends, although neither reached statistical significance. Overall, the RM-ANCOVA results showed that the Summer Bridge Program was effective in strengthening social integration and university integration, while academic and professional constructs showed positive but smaller gains.

Discussion

The findings of this study highlight the differentiated impact of the Summer Bridge Program across multiple domains of student development, offering important insights into how early interventions support first-year engineering students. As shown in **Figure 1**, all constructs measured demonstrated increases from pre- to post-program. Consistent with prior research, the SBP appeared most effective in strengthening social integration, an outcome linked to persistence in engineering pathways [28]. The significant and large improvement in students' sense of inclusion suggests that structured cohort activities, bonding experiences, and early exposure to engineering peers created a supportive environment that facilitated students' social adjustment before entering the formal curriculum. This aligns with the MCCS framework, which identifies peer-interaction support as a critical contributor to students' integration and undergraduate experience success [22].

Institutional awareness also increased significantly, indicating that explicit orientation to campus resources, expectations, and engineering culture helped students navigate institutional structures more confidently. Early familiarity with faculty and institutional norms has been shown to reduce uncertainty and improve first-year academic transition [29]. These gains reinforce the value of intentional program design that combines academic preparation, guided introduction to institutional and departmental support systems. In contrast, academic and professional development constructs showed more modest gains. These patterns are consistent with prior findings that academic self-efficacy evolves gradually as students encounter authentic tasks and feedback during their first year [30].

The limited improvement observed in the career expectation construct may be partially explained by a ceiling effect, as students entered the program with relatively high levels of career confidence. Additionally, students may require more sustained or iterative exposure to problem-solving contexts and industry engagement before measurable changes occur, particularly given the short duration of summer bridge programs. While short-term interventions can introduce students to engineering careers, they may not provide sufficient depth to significantly influence students' career expectations.

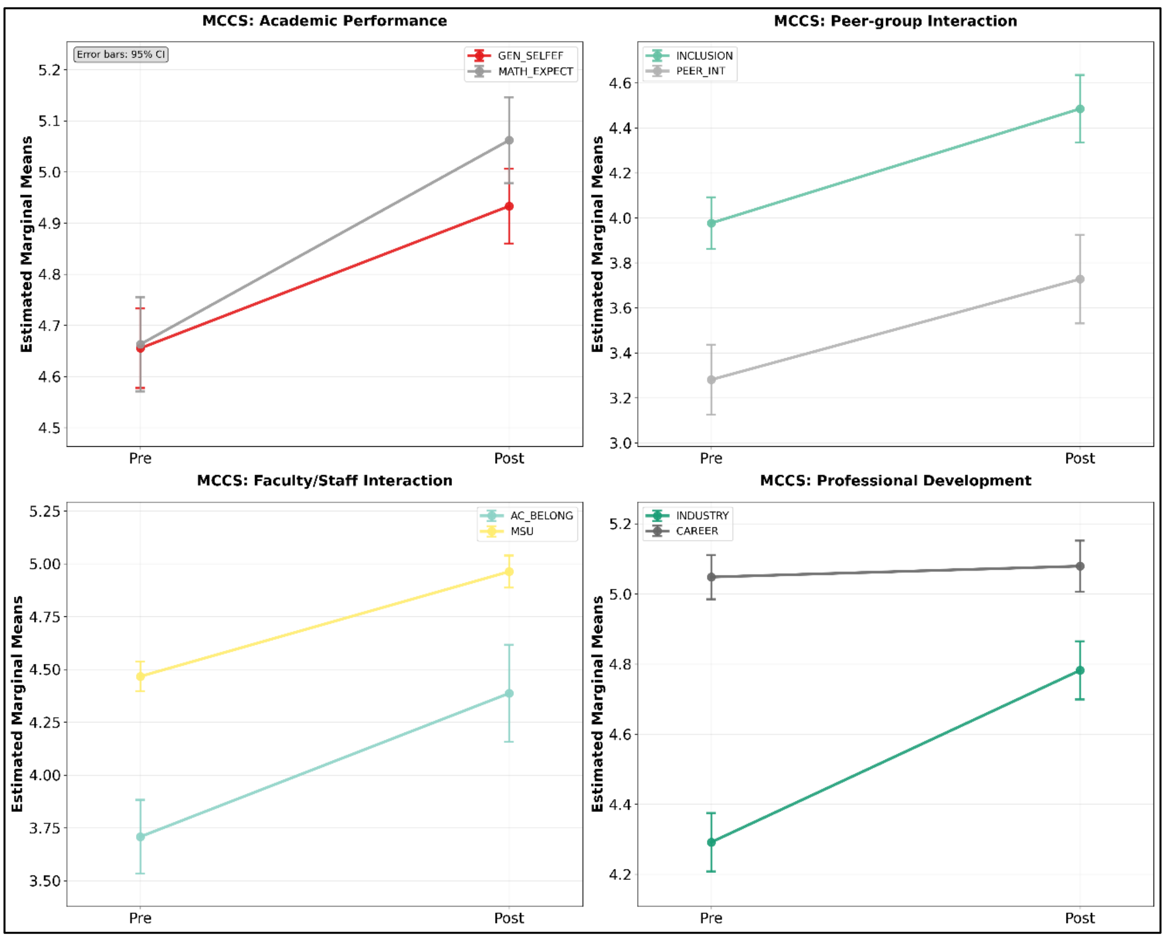

Figure 1. Comparison of Pre- and Post-survey mean scores across assessment instruments

Overall, the study demonstrates the importance of aligning program goals with validated constructs grounded in a theoretical framework such as the MCCS. By identifying the domains where gains are strongest, this approach helps institutions refine which program components contribute most to student success and where additional support may be needed. The results also provide a foundation for improving assessment practices in engineering education by encouraging the use of domain-specific, rather than relying on academic indicators or broad program satisfaction metrics.

Conclusion

This study examined the impact of a five-pillar Summer Bridge Program on first-year engineering students' academic performance, peer-group interaction, university integration and professional development using a theory-driven assessment approach aligned with the MCCS framework. Results from the RM-ANCOVA analyses indicated meaningful improvements across several domains of student development, particularly in social inclusion and institutional awareness. Academic self-efficacy and career development constructs also showed positive gains, though effects were smaller and did not consistently reach statistical significance. Collectively, the findings suggest that SBPs are especially effective at addressing the social and institutional challenges that often affect early engineering persistence. By aligning program goals with validated measures and a cocurricular support model, this study provides a replicable assessment approach that can strengthen the evaluation of early engineering interventions. The results reinforce the value of data-driven, co-curricular strategies in promoting a smoother transition into engineering and supporting first-year retention efforts.

Limitations

This study is subject to several limitations. First, the quasi-experimental design lacked a control group, limiting causal inference and making it difficult to rule out external influences on observed gains. Participants were selected into the SBP based on institutional criteria, introducing potential selection bias that may limit generalizability. The sample was drawn from a single institution in the southeastern United States, which further restricts the transferability of findings to other contexts. Finally, some constructs showed limited sensitivity to change over a short intervention period, suggesting the need for complementary qualitative measures or longer-term assessment.

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