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Summer Bridge Programs for Engineering Students: A Systematic Literature Review

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Engineering Summer Bridge Programs: A Systematic Literature Review

Abstract

Introduction: Engineering programs continue to struggle with attracting and retaining students from underrepresented groups. A variety of programs seek to improve equity in engineering programs, including summer bridge programs, which involve students transitioning in their studies, usually from high school to college. Summer bridge programs can vary dramatically in terms of time commitment, content, goals, and program evaluation methods.

Objective: The main purpose of this study is to explore the question, What does previous research indicate about engineering summer bridge programs?

Methods: Research studies involving engineering summer bridge programs ($n = 72$) were analyzed in this systematic literature review.

Results: Our findings indicate that summer bridge programs for engineering students often (1) focus on calculus skills, (2) have the goal of encouraging retention of minoritized students, and (3) occur in tandem with other interventions. While some studies use rigorous methods to assess program outcomes, other studies are more akin to experience reports.

Conclusion: Our findings present a landscape of research on summer bridge programs, including significant gaps in what is known about program efficacy.

Introduction and Background

The term ‘summer bridge program’ (SBP) describes a wide variety of programs that aim to support a student’s transition, usually from high school to college. The typical program is residential, spans multiple weeks, and focuses on improving academic performance and/or effective attributes. [1] These programs are frequently identified as one of the more effective ways to improve student outcomes, including retention, in engineering programs. [2] A 2008 meta-analysis found that SBPs focused on math instruction for engineering students had much success in the short term (although studies often lacked longer-term data). But these programs are resource-intensive, normally involving substantial costs related to planning, staffing, housing, activities, and evaluation. It is important that institutions that sponsor – or that are considering sponsoring – a SBP understand what program features contribute to accomplishing program goals and, perhaps more importantly, which features may impede those goals. A necessary first step to this process is understanding the landscape of research on SBPs. This paper is a contribution to such an effort, as it seeks to explore the question, What does previous research indicate about engineering summer bridge programs?

A previous review of literature on SBPs examined works published from the 1980s to 2012. It found a wide variety across various aspects of SBPs, including program curriculum, administration, and participation; [3] it also identified a lack of adequate research focused on identifying promising practices for SBP design and implementation. Another review examined literature (including non-peer-reviewed literature) that had been published about STEM SBPs between 1992 and 2016, with a focus on program goals. [4] The authors identified 14 different program goals, falling into three major categories: academic success, psychosocial, and departmental. Another review, published in 2023, focused on SBPs serving Native American students [5] and focused on identifying guidance; that guidance included adoption of contextual culturally relevant teaching practices, recognizing indigenous worldviews, respecting community and family, and supporting indigenous knowledge systems.

Methodology

Khan et al. established a process for conducting a systematic literature review: [6] (1) frame the question, (2) identify relevant work, (3) assess study quality, (4) create a summary, and (5) interpret findings. We have framed the question in the previous section. Khan et al.'s final two steps, summary and interpretation, are found in the Results and Discussion sections below.

In addition to following the Khan et al. methodology, we also observed the guidelines found in the PRISMA 2020 statement, [7] specifically the paper and abstract checklists. Figure 1 is a PRISMA diagram summarizing the process by which articles were identified for inclusion.

The SCOPUS database was searched in October 2023 via the query **ABS (engineering) AND ABS ("bridge program" OR "summer bridge" OR "summer boot camp" OR "summer college program" OR "summer college preparation program")**. A total of 231 records were identified, with 9 excluded because they were written in a language other than English or were a conference review, review, or book chapter. The remaining records were entered into Rayyan.ai. [8] (Note that Rayyan.ai's AI features were not used in this study.) Studies were excluded if they were duplicates ($n = 11$), not focused on a bridge program for students studying engineering ($n = 84$), or published before 2012 ($n = 55$). The remaining 72 studies were included in this review.[1]

[1] The included studies are McCord Ellestad et al. [9], Jura and Gerhardt [10], Harris et al. [11], Shandliya et al. [12], Chandra et al. [13], Orr et al. [14], Stephens et al. [15], McSpedon et al. [16], Cohan et al. [17], Espiritu and Todorovic [18], Fogg et al. [19], Griggs et al. [20], Nease et al. [21], McSpedon et al. [22], Cohan et al. [23], Freeman et al. [24], Birkes et al. [25], Quiroga et al. [26], Norouzi et al. [27], Tripathy et al. [28], Russell [29], Castaneda et al. [30], Cohan et al. [31], Tripathy et al. [32], Sanders et al. [33], Nazempour et al. [34], Gaskins and Clark [35], Roberts [36], Cohan [37], Nite et al. [38], Freeman et al. [39], Cohan et al. [40], Rahemi et al. [41], Song and Ma [42], Vollstedt [43], Brown et al. [44], Adams and Carter [45], Smith et al. [46], Nite et al. [47], Lee et al. [48], Whalin et al. [49], Parrish et al. [50], Taylor et al. [51], Nite et al. [52, 53], McSpedon et al. [54], Johnson [55], Vercellino et al. [56], Cairncross et al. [57], Hasenwinkel and Pynn [58], Dimitriu and O'Connor [59], Zhou et al. [60], Stwalley et al. [61], Nite et al. [62], St. John et al. [63], Zhou et al. [64], Lee et al. [65], Volcy [66], Reisel et al. [67], Doerr et al. [68], Erickson-Ludwig and Clyne [69], Dimitriu and O'Connor [70], Whalin and Pang [71], Hurtado et al. [72], Volcy and Sidbury [73], Knight et al. [74], Citty and Lindner [75], Heymans et al. [76], Jassemnejad et al. [77], Maton et al. [78], Reisel et al. [79], Worley et al. [80], Reisel et al. [81]

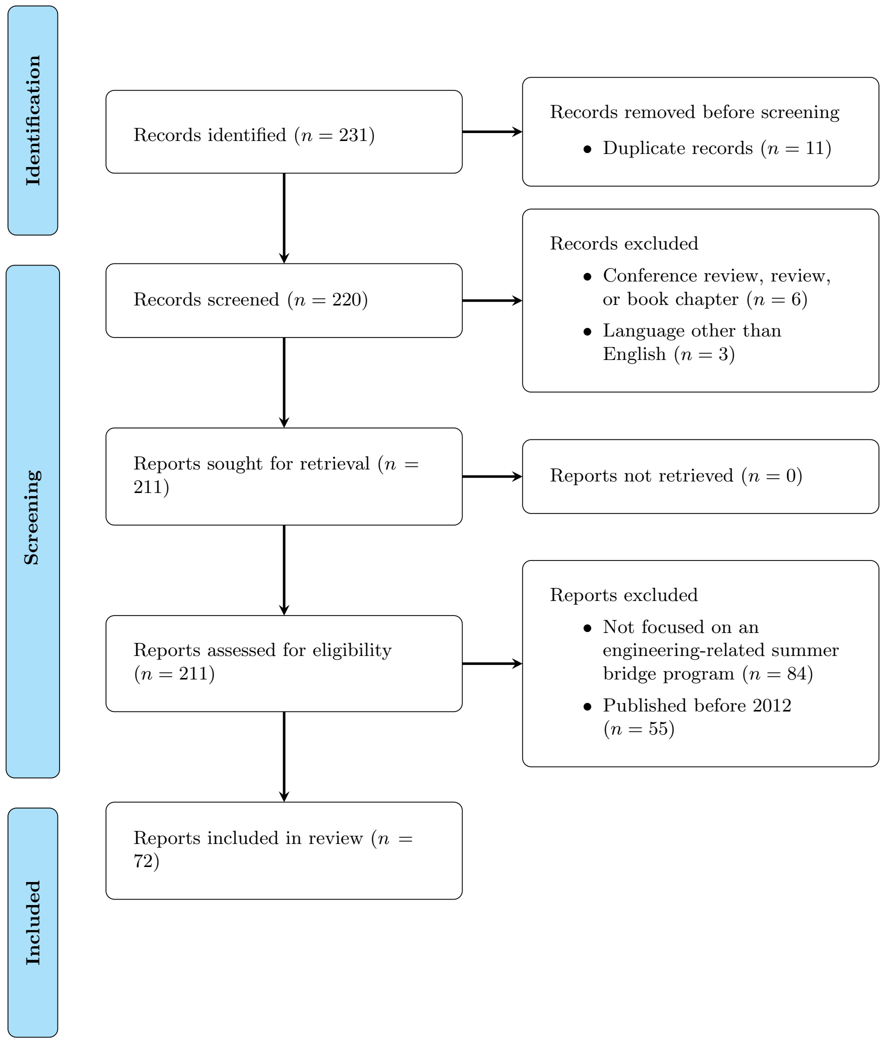

Figure 1: PRISMA chart

We deemed all of these studies to be of acceptable quality to include in this review, noting that many are more akin to experience reports than to formal research studies.

Included studies were reviewed to collect the following data points:

- target audience stage (e.g., transitioning from high school to a four-year college) and characteristics (e.g., women)
- program characteristics, including goal, content, length, and additional components
- program evaluation methods and measures
- program evaluation results

Results

Figure 2 shows the count of articles included in this review by year of publication. (Note that the data for 2023 is incomplete since the SCOPUS search was conducted in October of that year.) The trend line indicates that the number of publications tends to be roughly stable over time. This finding is in contrast to that of Ashley et al., who found in 2017 that the number of publications related to SBPs was increasing. [4]

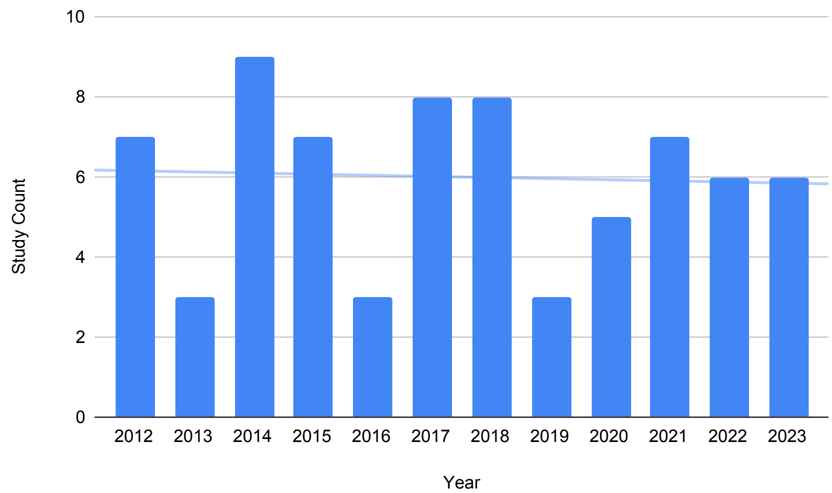

Figure 2: Count of studies per year.

Table 3 shows the publication venue for each included study, including journal articles (13.9%), the ASEE NSF grantee poster session (15.3%), other ASEE conference sessions (56.9%), and other conferences (13.9%).

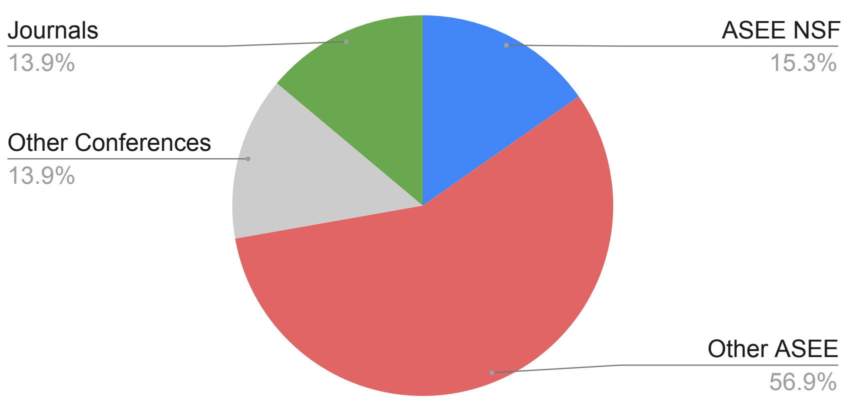

Figure 3: Publication venue.

Table 1 shows the transition type of SBPs. (Programs categorized as “4-year college → 4-year college” or “high school → high school” are programs for students transitioning from, for

Transition	Count
high school → 4-year college	62
4-year college → 4-year college	3
high school → high school	2
community college → 4-year college	2
high school → community college	1
4-year college → graduate program	1

Table 1: Type of summer bridge program.

example, the first to the second year at the same institution.) By far the most common type of program targets students transitioning from high school to a 4-year college.

Some studies indicate that their SBP focuses on a subset of students making the transition from one educational level to another; for these articles, the subset would involve students with unmet financial need, membership in a group that is underrepresented in engineering (e.g., women, first generation students, racially minoritized), low math scores, and/or considered “at risk.” Further, virtually all programs are focused on STEM students or engineering students generally and not on students in more specific program units.

Table 4 shows the length of SBPs. (In a few instances, a study described program iterations with different lengths; in these cases, the shortest length was used in the analysis.) There is a clear preponderance of four- and five- week long SBPs.

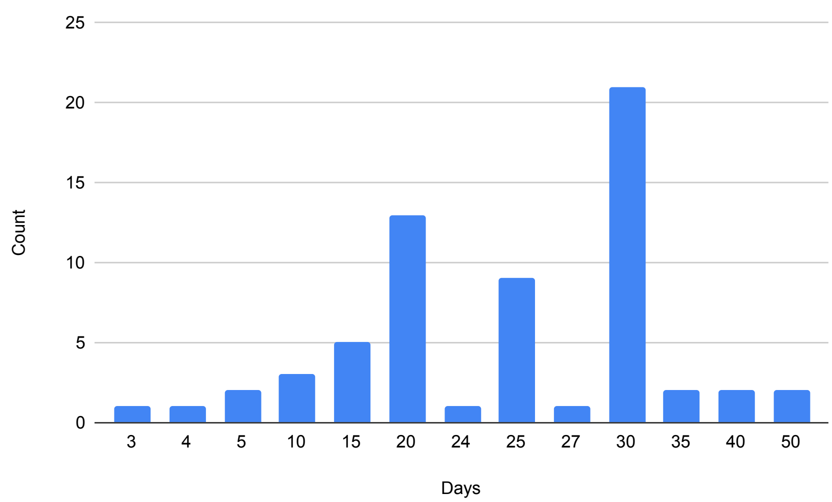

Figure 4: Program length.

Table 5 shows the count of student participants in each study. (In instances where a study had a control group, those students are not included in this count of participants.)

Programs often have components in addition to SBPs, and these additional components may or may not be mentioned in the study. Commonly mentioned additional components include the following:

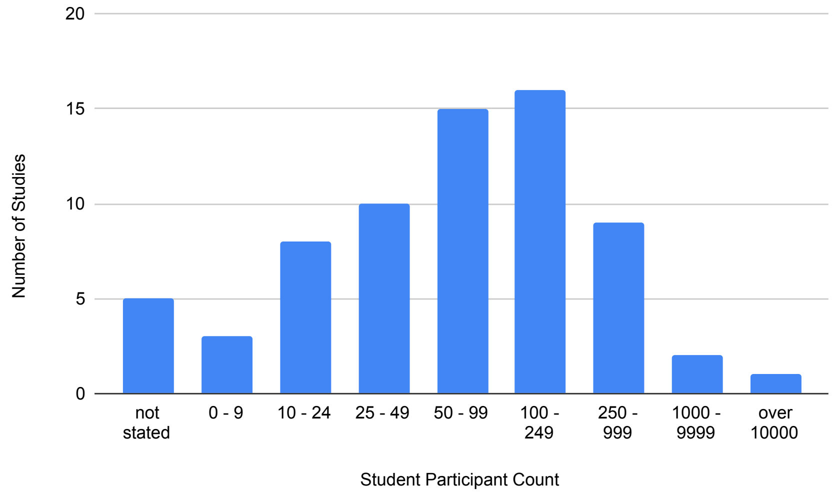

Figure 5: Count of student participants.

- scholarships
- coaching and mentoring
- cohort model (e.g., learning community, study and/or gathering space)
- community-building activities during the upcoming academic year
- tutoring
- counseling and/or advising

Figure 6 shows the type of study where specified in the article ($n = 66$). Quantitative results – usually in the form of grades, test scores, and/or retention rates – are the most commonly reported, and these normally use a pre- and post- intervention design as opposed to a comparative (e.g., across different SBPs) design.

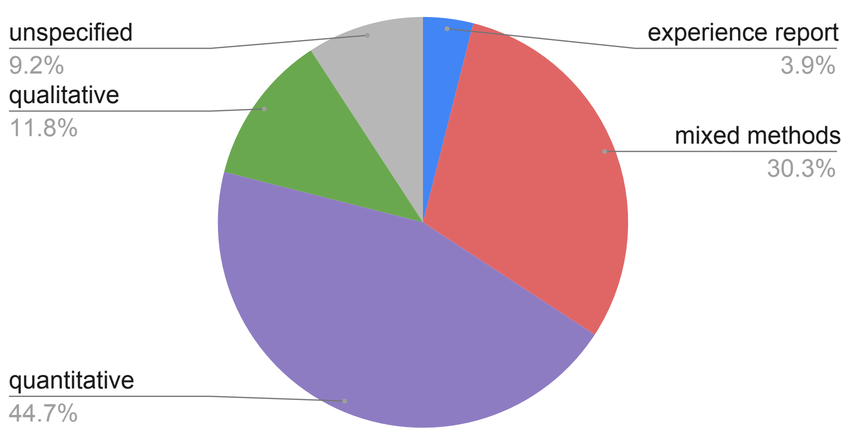

Figure 6: Study type.

About two-thirds (67.1%) of studies described a SBP that included math content, usually at the pre-calculus or calculus level. (In only a small number of programs, students may select from various content offerings.) Other frequently-mentioned content included engineering principles (often presented in a project-based manner), study and/or metacognitive skills, physics, and chemistry.

We categorized each program's goals as academic (e.g., improve math skills), retention (e.g., increase the number of students completing an engineering major), or affective (e.g., cultivate a community). Figure 7 shows the results of this categorization. SBPs are less likely to include solely affective goals ($n = 6$) and are more likely to involve either (1) a combination of affective and academic goals ($n = 16$), (2) solely academic goals ($n = 14$), or (3) solely retention-related goals ($n = 22$). As described above, academic goals usually focus on math skills. Affective goals often focus on confidence, social integration, motivation, and similar constructs.

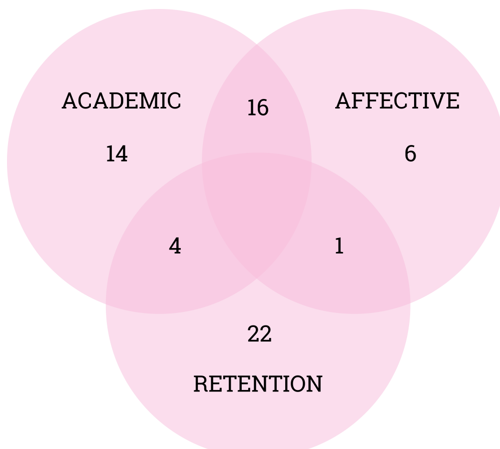

Figure 7: Summer bridge program goals.

Study Results

The most commonly reported result was an improvement in student retention. Studies also found positive effective results, including high levels of satisfaction with the program, intent to persist in STEM studies, improved self-efficacy, sense of belonging, confidence, motivation, sense of preparedness for future studies, and understanding of the engineering profession. There were also reports of improved academic skills, including spatial reasoning, metacognition, and math. Null or negative results are rarely reported, although there were sporadic reports of no impact on student's sense of belonging, sense of "excitement" for the major, math learning, or future grades.

Identified Best Practices

Some studies reported suggestions for implementing SBPs, including:

- schedule portions of the bridge program in various locations (i.e., avoid having students sit in one classroom all day) [32]

- for programs targeting specific student populations, invite those on campus with expertise (e.g., a Dean of Inclusion) to participate in program planning [82]
- leverage extant campus services such as tutoring centers and career services [24]
- be prepared to respond to instances of student misconduct [24]

Discussion

We found that the quantity of research on SBPs is roughly stable over time and often published via the ASEE annual conference. SBPs tend to focus on academic skills (usually math) and/or effective outcomes. While there is a wide range of program lengths, four or five weeks were most common, and almost all SBPs target the transition from high school to a four-year college. Studies report generally positive results, including in math performance.

One tension that emerges from the effort to synthesize studies of SBPs is that there is a spectrum from research that describes specific outcomes of one component of a SBP (e.g., development of spatial skills) to research describing the outcomes of efforts that include SBPs combined with academic year activities including service requirements, mentoring, scholarships, and so forth. At both ends of the spectrum, it can be difficult to assess the SBP: with narrowly focused studies, because other aspects of the SBP are underreported and, with broader efforts, because it is not possible to disambiguate the impact of the SBP from that of other program elements. In neither case does a clear picture of the SBP emerge from the study, making the task of gaining a broader view of the landscape of research on SBPs difficult. Even when programs are defined at similar levels of granularity, comparing SBPs that are of vastly different lengths and have different content, goals, target audiences, and evaluation measures is often not possible at the level of specificity that would be ideal for developing a full picture of SBP best practices.

Recommendations for SBPs and for researching SBPs based on the findings of this study are summarized in Figure 8.

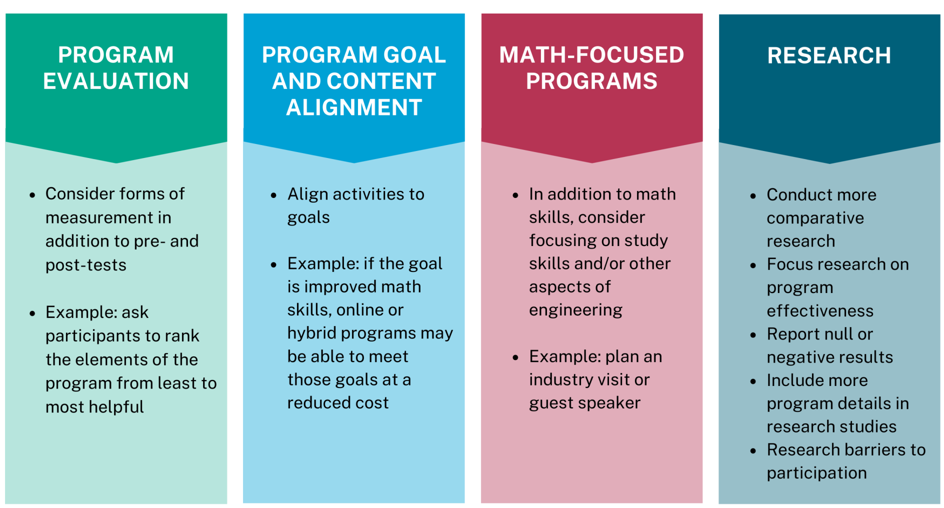

Figure 8: Recommendations for Summer Bridge Programs

SBP Recommendations

Program evaluation SBP program evaluators should consider – in addition to pre- and post-tests of academic and effective outcomes – other forms of measurement to provide additional information. For example, asking student participants to rank the separate elements of an SBP or to rank the SBP in comparison to other offerings (e.g., academic year monthly meetings) can provide additional information about what aspects of the SBP are perceived as beneficial.

Goal and content alignment Ashley et al. recommended carefully aligning the goals of an SBP with what outcomes are measured. [4] We would add that activities should be aligned as well. For example, if the goal is to improve math skills, online or hybrid versions may be more cost-effective than in-person SBPs and have similar outcomes, but a program with effective goals will be more likely to require in-person meetings. An SBP with both academic and effective goals may benefit from a hybrid format, with virtual content instruction and in-person community building, in order to manage costs.

Considerations for math-focused programs As described above, many SBPs are focused on improving students' math skills, and SBPs appear to be generally effective in meeting this goal. However, math skills and content knowledge alone may not suffice: some students may also need assistance in developing the study skills and mindset necessary to succeed in college-level math courses. For example, one study of SBP participants found that slightly more than half believed that the strategies effective in their high school math classes would suffice for earning high grades in college-level math, [83] but this may not be the case. And while mathematics performance has been a good predictor of retention in an engineering program, [84] it is also the case that an SBP focused entirely on math skills may inadvertently reinforce misconceptions about engineering as a discipline. Thus, it may make sense to balance a math-focused SBP with, for example, industry visits, cooperative projects, creative activities, exploration of societal and ethical implications of engineering, and so forth. Because a significant challenge faced by SBP participants is a sense of deep scrutiny from faculty, [85] it may be particularly helpful to integrate opportunities for positive, low-stress interactions into math-intensive SBPs.

Research Recommendations

This study confirms the findings of a previous review of SBPs, which found that, given how common SBPs are, there is relatively little research on their outcomes. [3, 4] Further, the findings of this review match those of Lee et al., [86] who found that most published reports related to SBPs are more akin to experience or evaluation reports than to formal research studies, and the resulting research landscape therefore lacks guidance for those interested in inaugurating or improving a SBP. A stronger comparative research base (e.g., contrasting outcomes of programs at multiple sites, or different iterations of a program at one site) would be helpful in determining promising practices for SBP program design. This study design would also result in larger participant populations, something that is particularly important given that the generally small nature of an individual SBP (often just a few dozen students) makes it difficult to compare the outcomes for different student demographic groups. Given the not-insignificant costs of SBPs, research focused on improving their effectiveness is pivotal. It may also be useful to report more null or negative results – something that was relatively rare in the articles included in this study –

to guide the development of other SBPs. [4]

We affirm the findings of Ashley et al.'s 2017 SBP literature review, which recommended that research include more program details. [4] It may be preferable for authors to select venues (such as the ASEE conference) that do not have maximum page length guidelines, or to place additional information (e.g., admissions process, daily schedule, budget information) in a linked online repository. Similarly, if, for example, ASEE were to articulate reporting guidelines, it would make an enormous difference in the SBP research landscape since they are publishing nearly three-quarters (72.2%) of SBP articles.

We did not identify any research focused on barriers to participation in SBPs. We hypothesize that such barriers might include cost (including lost wages), competing demands (e.g., caretaking responsibility), accommodations for students with disabilities, and lack of information, among other factors. To the extent that SBPs are beneficial, it is correspondingly important to identify ways to design them to be accessible to all students.

Conclusions

We note that there is a difference between the landscape of SBPs and the landscape of *research* about SBPs. It may be helpful for additional research to explore the broader landscape since some SBPs have less peer-reviewed research output than others, and understanding the broader landscape is also important. In general, a broader research base on SBPs is likely to be useful in meeting program goals.

Acknowledgements

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