A Meta-Analysis of STEM Bridge Programs at Four-Year Colleges

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Abstract*— Many universities and colleges aim to increase the retention of science, technology, engineering, and math (STEM) students through voluntary, university-sponsored, co-curricular programming. Bridge programs represent a common type of co-curricular activity and are often made up of additional coursework and skill-building activities designed to prepare students academically for STEM studies. Many Bridge programs are aimed at increasing the participation of students historically underrepresented in STEM. The design of bridge programs can vary quite drastically, as they may include or exclude different program elements, such as STEM-related workshops, faculty mentorship, and financial scholarships. In addition, the effectiveness of a bridge program on STEM major retention is influenced by the institutional context in which they are administered. Despite their popularity, few studies have sought to estimate the overall effectiveness of these programs on STEM major retention. This study isolates the effect of STEM-related workshops on its overall effectiveness on retaining STEM students. To study the overall effectiveness of STEM bridge program across various institutional contexts, we performed a meta-analysis of peer-reviewed literature by first performing a systematized literature review, and then combining and averaging relevant quantitative results into one overall odds ratio. We present the results of a meta-analysis on STEM bridge programs that provide workshops, and report on its effect on student STEM retention at the 1-, 2-, 3-, and 6-year marks. Search strings developed for this meta-analysis yielded 638 unique records from four databases. From these, 10 unique studies were selected for inclusion due to their relevance to this study and because they provided quantitative results that could be included in the meta-analysis. Results show that this subset of STEM bridge programs have a small effect on one-year STEM retention (Odds Ratio [OR] = 1.250). Long-term effects are also limited and show a slight decreased effect by year six (OR = 1.244). While this research includes only a limited number of available studies providing quantitative data, this study highlights the potential of using meta-analysis methods to broadly analyze program effectiveness. Our results highlight the importance of purposeful STEM bridge program design and how it may impact the retention of future STEM students. Future meta-analysis work on STEM bridge programs will look at the combined and isolated effects of other program elements, such as faculty mentorship, on STEM student retention.

Keywords—STEM bridge, retention, university

I. INTRODUCTION

Despite recent dips in the economy due to COVID-19, the U.S. expects to see considerable occupational growth over the next decade. More specifically, the U.S. Bureau of Labor Statistics predicts that STEM occupations will grow at over twice the rate (10.8%) of non-STEM occupations (4.9%) between 2021-31 [1]. STEM student retention rates, however, remain low. A study conducted at the University of Chicago, for example, showed an average cumulative 5-year graduation rate of 60.1% of first-time, full-time freshman STEM majors since 2010 (University of Illinois Chicago, 2020). Researchers have pointed to several factors as reasons for why undergraduate students leave the STEM major, including: loss of confidence due to grades; feeling unwelcome in the competitive STEM environment; poor teaching quality of STEM faculty; courseload difficulty; and loss of interest in STEM [2].

In response to this, the U.S. government has invested considerable resources and efforts towards STEM education; in 2020, for example, the U.S. Department of Education (DOE) awarded $578 million dollars towards STEM education initiatives compared to $540 in the previous year [3]. In addition, the U.S. Committee on STEM Education seeks to build strong foundations for STEM literacy, increase diversity, equity and inclusion in STEM fields, and prepare STEM graduates to enter into the workforce; in particular, there is interest in prioritizing funding for projects focused on STEM learning and engagement [4]. As such, there is great interest in developing bridge programs aimed at increasing STEM retention rates by providing students with the knowledge and skills to navigate the rigorous academic demands of STEM program [2], [5]. As there is great interest in understanding the connection between STEM bridge program and STEM retention, this study seeks to answer the question,

What is the effect of STEM bridge program participation on STEM major retention?

II. LITERATURE REVIEW

Bridge programs are described as campus-led intensive experiences aimed at helping students navigate college and improve academic success [6]. These programs, often taking place over the course of a summer, are often used to compensate

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for varying levels of educational opportunities and access of incoming college students [7]. Typically, these programs aim to incite student growth in three key areas: (a) academic content, which include content knowledge in gateway courses; (b) counseling-related content, such as study skills, time management, and college orientation; and (c) relationship building, such as having peer mentors and using a cohort model [8].

Participants for STEM bridge programs are often identified and recruited based on at least one of three measures: (a) the student is part of a specific major that is the focus of the program; (b) the student belongs to a certain target population, such as first-generation or low-income students; and/or (c) the student entered with lower science or math achievement scores or placed into remedial math [7], [9]. STEM bridge programs, in particular, are specifically designed for students majoring in STEM. Some bridge programs of this category are open to all STEM majors, with program elements broadly including math and science support. Other programs are designed specifically for STEM students in a particular major, such as chemistry or biology; the most common type of these bridge programs exist for engineering majors [6]. In addition, most of these programs are geared towards traditional incoming first year students. Others focus on students transferring from two-year community colleges to a four-year college or university setting [6]. Rare are programs that take place beyond the first year of university or college; Penn State, for example, hosts a yearly summer bridge program for engineering students between their first and second years aimed at improving student success in their sophomore year fall coursework [10].

Although most bridge programs follow the recruiting and admission standards described above, modes of participation and engagement vary quite drastically between programs. Some offer programming purely online as Penn State [10], while others are fully in person or take on a hybrid format [11]. In addition, participation time can vary. Some programs last for a few days, while others last for two months or more [6]. Most STEM bridge programs offer some instruction in gateway math and science courses, while others, particularly in engineering, offer project-based hands-on experiences [12]. Many STEM bridge programs also offer participants counseling-related content that may contribute to their academic success later. These topics may include study skills, note-taking and time management, or being exposed to various on-campus resources [7], [13], [14]. Finally, many programs may institute a peer mentorship model, wherein participants have supplemental instruction or mentorship by peers who share the same major or have participated in the same program [15]. Less common but still prevalent components of certain STEM bridge programs include opportunities for research, internships, and scholarships [16], [17].

The research shows that there are numerous positive outcomes to STEM bridge programs, particularly in areas regarding a student's confidence to success [15], [16]. Many studies report encouraging outcomes regarding course performance, and retention and graduation rates. Walpole et al., for example, reported on a summer bridge program designed for low income or poor academically performing incoming freshman [18]. Their findings indicated that the bridge program helped bring the GPA of program participants up to college averages, as well as increased retention rates. In another study, Douglas and Attewell studied transcript data from the Beginning Post-Secondary longitudinal study, and found that summer bridge programs had an effect size of 9.31% on 6-year graduation rates in low-selectivity colleges [19]. Others, however, report having mixed or no results. In a two-year follow-up of a summer bridge program in Texas, Barnett et al. found no evidence that program had any effect on persistence [20]. These findings suggest that, while these programs are indeed promising, more research is needed to investigate both the long-term impact of bridge programs, as well as the individual factors that make them effective.

It is possible that the mixed results of bridge program outcomes are due to the vastness of program variations. Given the varying contexts of both the participants and the nature of their engagement within the program, variation on program effectiveness is expected. Our study seeks to find the mean effect of STEM bridge programs on long term retention. A previous meta-analysis by Bradford et al. has been performed in this area [21] and reports an odds ratio (OR) of 1.747 ($p < 0.0001$) for one-year retention of students who participate in bridge programs compared to non-participants; in other words, they report that participants are 74.7% more likely to be retained in STEM after one year compared to non-participants. Bradford et al.'s study, while offering a promising outcome for summer bridge programs, includes all programs not differentiated by the types of programs they offer. In contrast, our work isolates the effect of summer bridge components, which include content knowledge instruction and counseling-related knowledge, from other forms of interventions and activities that are often administered as stand-alone programs (such as scholarship, research, or mentorship programs).

III. Methods

For this study, we performed a meta-analysis to understand the effect of STEM bridge programs on STEM major retention. The goal of a meta-analysis is to combine quantitative results from articles reporting interventions that selected for their relevancy to the research questions [22]. The first step in a meta-analysis is to perform a literature review to identify articles for inclusion. This review typically takes on the form of a systematic review; however, our study employs a systematized review [23]. Articles are selected for inclusion based on the parameters of the reported intervention (in our case, bridge programs), relevancy to the research questions, and quantitative results. These results are then combined to estimate the mean effect of the intervention in various contexts and cases.

A. Search Procedure

This study began by employing a systematized literature review as outlined by Grant and Booth [23] to investigate the impact of STEM related bridge programs on student retention. This meta-analysis is limited to peer-reviewed academic works that focus on STEM-related bridge programs. Our study seeks to find the isolated effects of bridge programs offering workshops in academic or counseling-related content. We chose to exclude bridge programs that included elements of faculty or industry mentorship, research, or offered academic scholarships, as these elements are also often offered by an institution outside of the context of a bridge program. We did, however, include bridge programs that included elements of peer mentorship, as they are commonly employed within programs to promote relationship-building.

STEM is defined as a discipline or study belonging to a science, technology, engineering, or mathematics field, as defined by the National Science Foundation (NSF) [24]. For our study, STEM bridge programs encompass voluntary, school-sponsored, co-curricular activities that are offered to enrolled students as early as the summer before their first term of enrollment. In addition, we limit this study to programs offered at four-year colleges and universities, as bachelor's degrees account for the majority of STEM degrees conferred, making this population is of special interest in building the U.S. STEM workforce [24]. Studies involving bridge programs administered at the pre-college or two-year college levels were excluded in this study. Finally, the term "retention" is used to refer to a student's later choice to stay within the STEM major at a given institution.

TABLE I. SEARCH STRINGS AND INITIAL RESULTS

Search String	Database	Initial Results
AB (STEM OR science OR technology OR engineer* OR math* OR chem* OR biol* OR physics OR programming OR coding OR computer OR geol* OR space OR marine OR environment*) **AND** TI (workshop OR bootcamp OR bridge) **AND** AB (university OR college OR higher education OR undergraduate) **AND** TX (retention OR attrition OR success OR graduation OR persistence) **NOT** SU ("high school" OR "middle school")	Education Source	105
AB (STEM OR science OR technology OR engineer* OR math* OR chem* OR biol* OR physics OR programming OR coding OR computer OR geol* OR space OR marine OR environment*) **AND** TI (workshop OR bootcamp OR bridge) **AND** AB (university OR college OR higher education OR undergraduate) **AND** TX (retention OR attrition OR success OR graduation OR persistence) **NOT** SU ("high school" OR "middle school")	ERIC	119
AB (STEM OR science OR technology OR engineer* OR math* OR chem* OR biol* OR physics OR programming OR coding OR computer OR geol* OR space OR marine OR environment*) **AND** TI (workshop OR bootcamp OR bridge) **AND** AB (university OR college OR higher education OR undergraduate) **AND** ALL (retention OR attrition OR success OR graduation OR persistence) **NOT** SU/TI ("high school" OR "middle school")	Engineering Village (Compendex and Inspec)	667

AB = abstract, TI = title, TX = text, SU = subject term, ALL = all text

We evaluated literature obtained from select databases using search strings that correlated directly to our research question. We used the Education Source and ERIC database sources, hosted by EBSCOhost, as well as Compendex and Inspec, hosted by Engineering Village. These databases were selected due to their content; the former databases are known to house peer-reviewed articles focusing on educational research, while the latter are known to house articles focusing on peer-reviewed engineering and science research. These four databases cover a breadth of educational research as it pertains to STEM fields and includes peer-reviewed content focused on STEM bootcamp development and outcomes.

The search strings did not vary greatly between databases. Each search term "STEM", "bridge", "college", and "retention" were varied identify a larger pool of articles relevant to the research question. The term "STEM" was varied to include all the sub-disciplines of STEM, such as engineering, chemistry, or computer science; these terms were selected to encapsulate NSF's accepted STEM discipline designations. As this study defines the term "bridge" loosely as school-sponsored, voluntary co-curricular activities, the term was expanded to include "workshop" and "bootcamp". The term "extracurricular" was not included in the search terms, as it yielded a large number of extraneous results involving middle- and high-school student activities. In our initial searches, the term "undergraduate" was frequently used in tandem with "college" in the literature. This search term was then expanded to include "university" and "higher education". "Retention" was also expanded to include "persistence" or "attrition" or "success" or "graduation", as these terms were often used in relevant papers to discuss a student's choice of staying within a

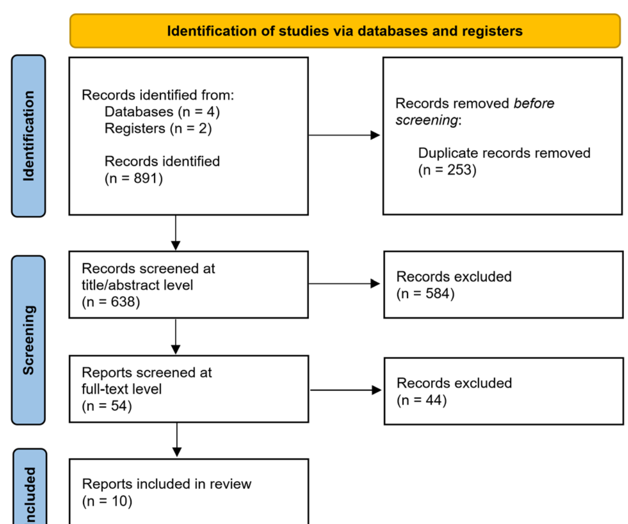

Fig. 1. PRISMA 2020 flow diagram, adapted from [25]

STEM major later. To limit the number of papers focused on middle- or high-school activities, articles listing "high school" or "middle school" as subject terms were excluded from this study; for Engineering Village, these terms were also excluded from titles. Table I details the search strings used in each of the databases, and the number of initial results. Of the 891 records yielded, 253 duplicates were removed, to yield 638 records.

B. Inclusion and Exclusion Criteria

We developed the inclusion criteria in tandem with the search strings during the initial search phase. To ensure that the articles directly addressed the goals of this study and the research question, papers were included if they:

- Were peer-reviewed journal articles or peer-reviewed conference papers
- Focused on students attending four-year colleges
- Focused on STEM bridge programs offered at four-year colleges

The exclusion criteria were developed during the title and abstract screening phase to ensure that unrelated search results were excluded. Search results were excluded if they:

- Were systematic, systematized, or narrative review articles
- Were written in any other language than English
- Took place at a college outside of the U.S.
- Did not report quantitative retention data
- Included mentorship, research, or scholarships as part of the bridge program

Of the 638 records screened at the title and abstract level using the exclusion criteria, 584 were excluded, leaving 54 to be screened at the full-text level. Of the 54 screened at the full-text level, 43 records were further excluded as they lacked usable retention data for the meta-analysis. An additional record [26] was also excluded, as it reported on the same bridge program as another record [27]. This resulted in 10 reports to be included in this study. An adapted PRISMA flow diagram [25] summarizing this study's systematized search process is presented in Fig. 1.

Analysis

1) Coding Procedures

All ten articles were read in their entirety to identify emergent themes that related to STEM bridge program and corresponding factors that influence retention. We performed the initial analysis by carefully reading each article, taking note of the primary focus of the article and research questions; these provided relevance for inclusion for this study. Following this,

TABLE II. SUMMARY FOR STEM BRIDGE PROGRAMS

ID	Citation	Treatment Eligibility	Control Group	Effect ID	Reported Retention Rates			
					1-year	*2-year*	*3-year*	*6-year*
1	Boykin et al., 2010 [27]	Freshman engineering students who placed into pre-calculus. Groups are split by cohort year.	All non-participant STEM students	1a	X	X	X	
				1b	X	X		
				1c	X			
2	Cançado et al., 2018 [12]	Freshman engineering students who placed in pre-calculus. Groups are split into three math ACT achievement levels.	Previous year cohort who did not participate in the program	2a	X	X	X	
				2b	X	X	X	
				2c	X	X	X	
3	Citty & Lindner, 2012 [28]	All freshman engineering students	Non-participant engineering students	3	X			
4	Cohan, 2018 [10]	Engineering students (priority to URM)	Non-participant student, matched pair	4	X			
5	Grimm, 2007 [29]	Freshman engineering students who placed into algebra or had low math achievement scores. Groups are split by cohort year.	Previous year cohort who did not participate in the program	5a	X	X		
				5b	X			
6	Kowalchuck et al., 2010 [30]	Freshmen engineering students who placed into pre-calculus. Groups are split by cohort year.	All non-participant engineering students	6a	X			
				6b	X			
7	Roberts et al., 2009 [31]	Freshman engineering students who identified as URM and had low math achievement scores	All non-participant engineering students	7	X	X		X
8	Stwalley et al., 2015 [32]	Any freshman engineering student (targeted URM).	All non-participant engineering students	8	X			
9	Vercellino et al., 2015 [33]	Freshmen engeering students with low math achievement scores.	All non-participant engineering students with matched achievement scores	9	X			
10	Whalin et al., 2017 [34]	Freshman engineering students with low math achievement scores. All participants to date have been African Americans. Groups are split by ACT scores.	All non-participant STEM students	10a	X	X	X	
				10b	X	X	X	

we recorded all reported outcomes including quantitative data, and took notes on the type of study, population, methodology, and findings. These were grouped to discover emergent themes.

2) Meta-Analysis Procedures

While only ten articles were included in this study, many articles reported outcomes for separate cohorts of students participating in their bridge programs. Many of these articles reported improving methods between cohort groups; as such, each cohort was recorded as a separate outcome to be included in the meta-analyses. Of the ten articles, seven reported 1-year retention rates, two reported 2-year retention rates, three reported 3-year retention rates, and one final one reported a 6-year STEM retention rate which included students who graduated with a STEM degree. This information, including information on the control groups, is listed by article in Table II.

IV. Results

A. Descriptive Results

Table III presents the program elements present in all ten of the articles reviewed for this study. All of the ten articles in this study focus on bridge programs aimed at engineering students, though some studies report STEM retention rates to accommodate for students who switch majors but stay in a STEM field. As these programs were primarily engineering-focused, it is unsurprising that seven of the ten articles include engineering-related related activities. None of the programs focus on engineering content instruction, but instead focus on experiential learning, which includes hands-on design or design competitions, field trips, and guest speakers.

Another common element of the bridge programs reviewed in this study includes content instruction on introductory math and science courses. Of these ten articles, nine include elements of math content instruction. This comes in the form of co-curricular math courses or supplemental instruction, either delivered in-person or online through programs such as ALEKS. Six of these nine programs also include co-curricular courses or supplemental instruction in introductory physics and/or chemistry.

TABLE III. Bridge Program Elements

ID	Program Elements					
	MATH	***PHYS***	***CHEM***	***ENGR***	***COUNS***	***PM***
1	X	X	X	X		
2	X			X		
3	X		X	X	X	X
4	X	X				
5					X	X
6	X			X	X	
7	X		X	X	X	
8	X	X	X		X	
9	X			X		X
10	X			X	X	
N	9	3	4	7	6	3

MATH = math, PHYS = physics, CHEM = chemistry, ENGR = engineering, COUNS = counseling, PM = peer mentoring

TABLE IV. STEM Retention Odds Ratio by Year

Year	***n***	**Odds Ratio**	**Pooled**				**Prediction Interval**	
			LL	***UL***	***Z***	***p***	***LL***	***UL***
1	15	1.250	1.005	1.556	2.000	0.045	0.730	2.142
2	17	1.352	1.048	1.745	2.321	0.020	0.553	3.308
3	17	1.274	1.024	1.584	2.177	0.029	0.639	2.538
6	17	1.244	1.002	1.544	1.984	0.048	0.630	2.455

LL = lower limit, *UL* = upper limit, *Z* = *Z* statistic, *p* = *p* value

Other components reported by the included articles involve counseling-related activities ($n = 6$) and peer mentorship ($n = 3$). Counseling related activities include elements of campus orientation, personal and professional development, and academic advising. Bridge programs mentioning peer mentorship as an integral part of the program involved the mentors in both counseling-related and instructional activities.

B. Meta-Analysis Results

The results of the meta-analysis for 1-, 2-, 3-, and 6-year STEM retention rates are reported in Table IV. The 1-, 2-, 3-, and 6-year odds ratios (OR) for STEM student retention are 1.250 ($p = 0.045$), 1.352 ($p = 0.020$), 1.274 ($p = 0.029$), and 1.244 ($p = 0.048$), respectively, and are significant at the $\alpha = 0.05$ level. In other words, students who participate in STEM bridge programs as defined by this study are 25% more likely to persist through to their first year compared to students who did not. The calculated 2-year retention odds ratio was higher than the 1-, 3-, and 6-year odds ratio, however this calculation also resulted in the greatest prediction interval. Given the overlapping confidence intervals between all four calculated ORs, we found that the 1-, 2-, 3-, and 6-year retention results remained fairly similar. Our results are unsurprising, as it has been shown in the literature that students who leave their STEM majors typically do so before starting their second year [35].

V. Discussion

For this study, we applied meta-analysis techniques to examine the effectiveness of STEM bridge programs on student retention. We found our model to be statistically significant, and that STEM bridge programs do increase the odds of STEM student retention by 25% in their first year, and 24.4% in six years including graduation. While there is some variation in the results for 2- and 3-year retention rates, the outcomes are fairly similar.

Our study was limited by the number of unique STEM bridge programs available for inclusion in this study. Despite extensive research on these interventions, relatively few studies report student retention rates beyond the program timeline. In addition, as bridge programs are generally targeted towards specific populations, they often result in small participant groups; in our study, the extreme case had a treatment group of only 13 students [30]. Finally, while our study attempts to combine the effects of STEM bridge programs, the programs themselves vary by content (i.e., the type of instruction) and context (i.e., location). With a larger sample size, these variations and biases could be further studied.

The limitations encountered in this study points to data collection as an area of improvement for future bridge programs. Bridge program administrators should consider program outcomes carefully and track additional outcomes beyond the program timeline. This includes long term success data, such as GPA, major retention, and college retention. In addition, while bridge programs exist at all types of higher education institutions, a majority of the research reporting retention outcomes on these programs exist at public doctoral degree granting institutions [6]. Previous studies have shown that STEM completion rates are influenced by institutional contexts [17], including factors such as institution selectivity. In particular, institutions with higher selectivity, which is often the case for doctoral degree granting institutions, see higher graduation rates compared to less selective institutions [36], [37]. To understand the full effect of summer bridge programs, we suggest future research in this area comprise of bridge programs at various types of institutions, and in particular institutions with lower selectivity and lower STEM retention rates.

Despite its limitations, our study highlights a much-needed gap in the literature – while many studies study short-term outcomes of STEM retention programs such as bridge programs, few study and report long term outcomes. In addition, our study shows a viable option for analyzing pooled outcomes for an intervention. Specifically, performing a meta-analysis allows policymakers and program managers to assess the mean effect size of an intervention before administration. Being able to produce a mean effect size across different studies performed under different contexts is particularly useful, as institutional context plays an important role in STEM degree completion rates [17]. While our study only focuses on STEM bridge programs, this work could be expanded to explore the effects of other retention programs and interventions, such as faculty mentorship, scholarships, internships, and research.

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References

[1] U.S. Bureau of Labor Statistics, "Employment in STEM occupations : U.S. Bureau of Labor Statistics," Sep. 08, 2022. https://www.bls.gov/emp/tables/stem-employment.htm (accessed Oct. 24, 2022).

[2] E. Seymour and N. M. Hewitt, *Talking About Leaving: Why Undergraduates Leave the Sciences*. Boulder, Colorado: Westview Press, 2000.

[3] U.S. Department of Education, "STEM investments FY18-20," 2019. https://www.ed.gov/sites/default/files/documents/stem/stem-investments-18-20.pdf (accessed Oct. 24, 2022).

[4] U.S. Office of Science and Technology Policy, "Progress report on the implementation of the federal STEM education strategic plan," Dec. 2021. https://www.whitehouse.gov/wp-content/uploads/2022/01/2021-CoSTEM-Progress-Report-OSTP.pdf (accessed Oct. 24, 2022).

[5] L. Tsui, "Effective strategies to increase diversity in STEM fields: A review of the research literature," *The Journal of Negro Education*, 2020.

[6] M. Ashley, K. M. Cooper, J. M. Cala, and S. E. Brownell, "Building better bridges into STEM: A synthesis of 25 years of literature on STEM summer bridge programs," *Life Sciences Education*, vol. 16, no. 4, pp. 1–18, Dec. 2017, doi: 10.1187/cbe.17-05-0085.

[7] A. Kezar, "Summer bridge programs: Supporting all students," ERIC Clearinghouse on Higher Education, One Dupont Circle, N, Jun. 2000. Accessed: May 16, 2023. [Online]. Available: https://eric.ed.gov/?id=ED442421

[8] J. R. Sablan, "The challenge of summer bridge programs," *American Behavioral Scientist*, vol. 58, no. 8, pp. 1035–1050, Jul. 2014, doi: 10.1177/0002764213515234.

[9] J. M. Kallison and D. L. Stader, "Effectiveness of summer bridge programs in enhancing college readiness," *Community College Journal of Research and Practice*, vol. 36, no. 5, pp. 340–357, May 2012, doi: 10.1080/10668920802708595.

[10] C. Cohan, "Promising practices for the expansion and sustainability of summer bridge programs for underrepresented engineering students at the Pennsylvania State University," in *Collaborative Network for Engineering and Computing Diversity Conference*, Crystal City, VA, United states: American Society for Engineering Education, 2018.

[11] J. R. Reisel, M. Jablonski, H. Hosseini, and E. Munson, "Assessment of factors impacting success for incoming college engineering students in a summer bridge program," *International Journal of Mathematical Education in Science and Technology*, vol. 43, no. 4, pp. 421–433, Jun. 2012, doi: 10.1080/0020739X.2011.618560.

[12] L. Cançado, J. R. Reisel, and C. M. Walker, "Impacts of a summer bridge program in engineering on student retention and graduation," *Journal of STEM Education: Innovations & Research*, vol. 19, no. 2, pp. 26–31, Apr. 2018.

[13] R. Evans, "A comparison of success indicators for program and non program participants in a community college summer bridge program for minority students," *Visions: The Journal of Applied Research for the Florida Association of Community Colleges*, vol. 2, no. 2, pp. 6–14, 1999.

[14] P. Garcia, "I," *Journal of the Freshman Year Experience*, vol. 3, no. 2, pp. 91–105, Jan. 1991.

[15] A. Brady and D. Gallant, "STEM bridge program: Underrepresented minority students' perceptions of Louis Stokes Alliance for Minority Participation Program impact," *Journal of College Science Teaching*, vol. 50, no. 6, pp. 57–62, Jul. 2021.

[16] M. Ghee, M. Keels, D. Collins, C. Neal-Spence, and E. Baker, "Fine-tuning summer research programs to promote underrepresented students' persistence in the STEM pathway," *Life Sciences Education*, vol. 15, no. 3, pp. 1–11, Sep. 2016, doi: 10.1187/cbe.16-01-0046.

[17] K. Eagan, S. Hurtado, and M. Chang, "What matters in STEM: Institutional contexts that influence STEM bachelor's degree completion rates," presented at the Association for the Study of Higher Education, Indianapolis, IN, 2010.

[18] M. Walpole, H. Simmerman, C. Mack, J. Mills, M. Scales, and D. Albano, "Bridge to success: Insight into summer bridge program students' college transition," *Journal of The First-Year Experience & Students in Transition*, vol. 20, no. 1, pp. 11–30, Jan. 2008.

[19] D. Douglas and P. Attewell, "The bridge and the troll underneath: Summer bridge programs and degree completion," *American Journal of Education*, vol. 121, no. 1, pp. 87–109, Nov. 2014, doi: 10.1086/677959.

[20] E. A. Barnett, R. H. Bork, A. K. Mayer, J. Pretlow, H. D. Wathington, and M. J. Weiss, "Bridging the gap: An impact study of eight developmental summer bridge programs in Texas," National Center for Postsecondary Research, Jun. 2012. Accessed: May 16, 2023. [Online]. Available: https://eric.ed.gov/?id=ED533824

[21] B. C. Bradford, M. E. Beier, and F. L. Oswald, *Life Sciences Education*, vol. 20, no. 2, Jun. 2021, [Online]. Available:

https://login.ezproxy.lib.purdue.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1301449&site=ehost-live

[22] M. Borenstein, L. V. Hedges, J. Higgins, and H. R. Rothstein, *Introduction to Meta-Analysis*, Second edition. Hoboken: Wiley, 2021.

[23] M. J. Grant and A. Booth, “A typology of reviews: an analysis of 14 review types and associated methodologies,” *Health Information & Libraries Journal*, vol. 26, no. 2, pp. 91–108, 2009, doi: 10.1111/j.1471-1842.2009.00848.x.

[24] National Science Foundation, “Science and engineering indicators 2022,” 2022. https://ncses.nsf.gov/pubs/nsb20223/demographic-attributes-of-s-e-degree-recipients (accessed Oct. 25, 2022).

[25] M. J. Page *et al.*, “The PRISMA 2020 statement: An updated guideline for reporting systematic reviews,” *BMJ*, vol. 372, p. n71, Mar. 2021, doi: 10.1136/bmj.n71.

[26] J. Gleason *et al.*, “Integrated engineering math-based summer bridge program for student retention,” *Advances in Engineering Education*, vol. 2, no. 2, pp. 1–17, 2010.

[27] K. Boykin, D. Raju, J. Bonner, J. Gleason, and L. Bowen, “Engineering math based bridge program for student preparation,” in *International Conference on Society and Information Technologies*, Orlando, FL, United states: International Institute of Informatics and Systemics, IIIS, 2010, pp. 231–236.

[28] J. M. Citty and A. S. Lindner, “Dual model summer bridge programs: A new consideration for increasing retention rates,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, San Antonio, TX, United states: American Society for Engineering Education, 2012.

[29] M. Grimm, “An engineering bridge program: Improving the success rate of underprepared students in engineering,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, Honolulu, HI, United states: American Society for Engineering Education, 2007, p. Dassault Systemes; DuPont; et al; HP; IBM; Lockheed Martin.

[30] R. Kowalchuk, T. Green, R. Ricks, and J. Nicklow, “Evaluation of a summer bridge program on engineering students’ persistence and success,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, Louisville, KY, United states: American Society for Engineering Education, 2010.

[31] S. Roberts *et al.*, “Evaluation of retention and other benefits of a fifteen-year residential bridge program for underrepresented engineering students,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, Austin, TX, United states: American Society for Engineering Education, 2009, p. BOEING.

[32] C. S. Stwalley, T. Zephirin, D. A. Dickerson, and V. L. B. Womack, “A description of the statistics behind analyzing performance data: A five-year study of an summer bridge program for incoming URM freshman,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, Seattle, WA, United states: American Society for Engineering Education, 2015.

[33] T. Vercellino, D. Christenson, and A. N. Morse, “Implementation and effects of a bridge program to increase student learning and retention in engineering programs,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, Seattle, WA, United states: American Society for Engineering Education, 2015.

[34] R. W. Whalin, Q. Pang, L. S. N. Lowe, and J. H. Latham, “Assessment of a summer bridge program: Seven years and counting,” in *ASEE Annual Conference and Exposition, Conference Proceedings*, Columbus, OH, United states: American Society for Engineering Education, 2017.

[35] L. Aulck, R. Aras, L. Li, C. L’Heureux, P. Lu, and J. West, “STEM-ming the Tide: Predicting STEM attrition using student transcript data.” arXiv, Aug. 28, 2017. Accessed: Feb. 04, 2023. [Online]. Available: http://arxiv.org/abs/1708.09344

[36] M. A. Titus, “An examination of the influence of institutional context on student persistence at 4-year colleges and universities: A multilevel approach,” *Research in Higher Education*, vol. 45, no. 7, pp. 673–699, 2004.

[37] M. K. Eagan, S. Hurtado, M. J. Chang, G. A. Garcia, F. A. Herrera, and J. C. Garibay, “Making a difference in science education: The impact of undergraduate research programs,” *American Educational Research Journal*, vol. 50, no. 4, pp. 683–713, Aug. 2013, doi: 10.3102/0002831213482038.