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A case study of a novel summer bridge program to prepare transfer students for research in biological sciences

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Abstract

Undergraduate research experiences enculturate students into the research community by providing support networks to explore advanced professional opportunities. However, transfer students are at a considerable disadvantage for pursuing these opportunities due to the time constraints imposed by institutional structures. Here, we report a case study of a novel summer bridge program to prepare incoming transfer students for research experiences in biological sciences. During the summer, participants committed to full-time program activities, including hands-on training with laboratory techniques through research projects and designing and executing an independent project. Pre- and post-program surveys were administered, and participants reported substantial gains in research self-efficacy and knowledge of scientific career pathways. Participants also reported strong learning and social support in the program. After the program, 30 out of 32 participants secured positions in faculty laboratories, with most continuing on to positions in industry, graduate programs, or medical and health professions. In a post-program interview, participants reported many benefits from the program, such as mentorship from faculty, developing transferable skills and research interests, and an easier transition from community college to university. While descriptive, this summer bridge program could inform future design-based research and implementations in different institutional contexts.

Introduction

Community colleges provide an important pathway to higher education for many students, especially those who have been historically excluded from science, technology, engineering, and mathematics (STEM) fields. About 41% of all U.S. undergraduates are community college students, and these students are more likely than those who enroll as freshmen to be first-generation students, socioeconomically disadvantaged, from racially or ethnically underrepresented groups, and veterans (American Association of Colleges and Universities, 2021; Bahr et al., 2013; Hagedorn et al., 2008; Hagedorn & Purnamasari, 2012; Ma & Baum, 2016; Rosenberg, 2016; Townsend, 2008). Although many of these students will transfer to four-year universities, these institutions rarely provide the resources these students need to navigate the academic and social transition to a new institutional culture. There are especially few resources to help transfer students pursuing STEM degrees gain the necessary research experience needed to matriculate into graduate studies and succeed in the STEM workforce.

For groups underrepresented in STEM, including transfer students, a career in scientific research is not easily accessible. Upon transfer to a four-year university, transfer students are immersed in challenging upper-division courses alongside peers who have already had two or more years to acclimate to the pace and culture of the campus. It takes time to learn about available research opportunities, interact with and build relationships with

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faculty, find mentors, and learn what steps are necessary for a successful application to graduate school. First-year admits can start working in research labs as they finish their introductory course work, during which they have time to become proficient in research skills and techniques, network into new research and professional opportunities, obtain strong letters of recommendation for graduate and professional programs, and in some cases, contribute to a co-authored publication (Ceyhan & Tillotson, 2020; Linn et al., 2015; Thiry et al., 2012).

In contrast, transfer students often have no context or introductions to faculty when transitioning to the university and spend a significant amount of their reduced timeframe learning how to navigate the campus on their own (Gamage et al., 2022; Hewlett, 2018; Jackson et al., 2013). By the time they become acclimated and learn about opportunities to become involved in research, it is often too late to meet the long-term time commitments that many laboratories require (Cooper et al., 2019; Hirst et al., 2014; Thiry et al., 2012). Furthermore, many transfer students have financial obligations that require them to hold jobs (Allen & Zhang, 2016; Reyes, 2011; Wang, 2021), which may limit the available time to work in a research lab as a volunteer. Research shows that these students are more likely to be daunted by the intimidating culture of STEM, and many students perceive that the academic and professional benefits of pursuing research opportunities are not worth the required time investment and potential financial costs needed to attain these benefits (Beasley & Fischer, 2012; Labov, 2012; National Academies of Sciences, Engineering, and Medicine, 2016; Reyes, 2011; Seymour & Hunter, 2019). As a result, few transfer students from underrepresented groups pursue a Ph.D. despite their intentions to pursue this track upon transfer to the university (Bettinger, 2010; Labov, 2012).

Research training is a key prerequisite for acceptance into competitive Ph.D. programs; for most Ph.D. programs, at least one year of research experience is essential for admission and is a significant component of an applicants' preparation for a rigorous, research-intensive graduate curriculum (Carter et al., 2009; Junge et al., 2010; McLoon & Redish, 2018; Pacheco et al., 2015; Rodenbusch et al., 2016; Russell et al., 2007; Seymour et al., 2004). Undergraduate research experiences are a high-impact institutional practice that provide students with the social support network, faculty mentorship, and academic and professional resources needed to pursue career and graduate school opportunities in STEM (Bangera & Brownell, 2014; Jones et al., 2010; Kuh, 2008; Thiry & Laursen, 2011). Research experiences offer a suite of academic and psychosocial benefits to participating students, including transformative impacts on career ambitions (Carpi et al., 2017; Estrada et al., 2018; Fechheimer et al., 2011; Russell et al., 2007), professional self-efficacy (Robnett et al., 2015; Sadler & McKinney, 2010), and increased sense of belonging to the campus community (Wilson et al., 2015). These psychosocial benefits are crucial for students who are beginning their journey in research as they can influence goal orientation and development of realistic expectations in future research opportunities (Adedokun et al., 2013; Larson et al., 2015; Maton et al., 2016; Robnett et al., 2015; Tate et al., 2015), and STEM intervention programs have proven especially beneficial for underrepresented students, including first-generation students and racially or ethnically minoritized students (Fakayode et al., 2014; Ghee et al., 2016; Maton et al., 2016; Pender et al., 2010).

While summer bridge programs are structured and administered in a variety of ways and target various student populations (Garcia & Paz, 2009; Kezar, 2000; Sablan, 2014), they almost exclusively support students who directly transfer to university from high school (e.g. Ackermann, 1991; Ashley et al., 2017; Kezar, 2000; Strayhorn, 2011; Suzuki et al., 2012). Bridge programs that focus on building transfer students' knowledge of campus resources as well as academic skills have shown to be impactful particularly for racially or ethnically minoritized and low-income students (Ackermann, 1991) and helping students build confidence and motivation in pursuing STEM degrees (Lenaburg et al., 2012). Building upon (a) exhaustive meta-analyses highlighting the positive impacts of undergraduate research experiences (e.g., Linn et al., 2015; Sadler & McKinney, 2010), (b) national conversations supporting the need to recruit diverse students in the STEM career pipeline (President's Council of Advisors on Science and Technology, 2012), and (c) a growing literature base discussing the unique challenges and needs of transfer students (Jackson & Laanan, 2015; Reyes, 2011; Wang, 2021; Zuckerman & Lo, 2021), we developed a summer bridge program to support transfer students from diverse backgrounds who were interested in pursuing research careers in biological sciences and other STEM disciplines. Our program was designed to orient transfers to research experiences so that they can become competitive with first year admits.

Using this summer bridge program as a case study, we measure psychosocial outcomes related to participants' affect toward their research experiences and professional aspirations in science after participating in the program, including their self-efficacy in research skills, knowledge of navigational processes in STEM careers and graduate school, and interest in continuing in a science major and career pathway. These psychosocial measures have been previously correlated with achievement and persistence in STEM (e.g., Ainscough et al., 2016; Ballen et al., 2017; Chemers et al., 2011; Hurtado & Ruiz, 2012), which we also documented by tracking participants' subsequent participation in undergraduate research experiences and continuation into graduate school and STEM career pathways. These outcome measures determine the extent to which the summer bridge program cultivated a supportive environment that enhanced student integration and confidence in performing practices central to communities of scientists. It was hypothesized that the social and navigational capital provided by the program would also provide students with the confidence to leverage helping relationships that would benefit them in navigating other academic, social, and professional experiences at the university (Karabenick, 2004; Ryan et al., 1998). We apply Lave and Wenger (1991) community of practice as a guiding theoretical framework to address the following research questions (RQs):

1. In what ways did the program impact cognitive and affective outcomes, subsequent participation in undergraduate research experiences, and occupational attainment in STEM career pathways for participating transfer students?
2. How did the summer bridge program support students' academic, social, and professional integration in the university?

Theoretical framework: research as a community of practice

A research-integrated summer bridge program for transfer students is a novel phenomenon in science education research and practice, and thus we apply a theoretical framework as a lens for interpreting the findings from a case study of this phenomenon (Luft et al., 2022). The design and implementation of the summer bridge program will be interpreted through the theoretical lens of learning in research as a *community of practice*. Here, we broadly review tenets and principles of the community of practice framework and then contextualize the application of this framework to our case study.

A community of practice is a social and cultural system that is defined by norms and values shared by a community that is engaged in learning through mutual goals, known as a *joint enterprise* (Lave & Wenger, 1991; Wenger, 2010). *Enculturation* into a community of practice depends on the activities, tools, and people within the sociocultural setting (Hodges, 1998; Lave & Wenger, 1991; Wenger, 1998). Enculturation is formalized through *legitimate peripheral participation*, where newcomers learn through engagement with experts in a situated context that is authentic and relevant. The historically defined relations of power can organize the way that individuals participate within the community, potentially empowering or marginalizing different groups based on identity and historical representation. Individuals who are effectively enculturated into the practice and seek to continue developing as a more centralized member experience an *inbound trajectory* into the community while those who lose interest or involvement experience an *outbound trajectory* (Fracchiolla et al., 2020; Prefontaine et al., 2021).

Salient features of a group classified as a community of practice include (a) a shared goal or proficiency, (b) interactions between group members that help individuals achieve the goals, and (c) common practices in the form of norms and shared information that can be used to achieve the goals (Prefontaine et al., 2021; Wenger, 1998). The scientific research community can be construed as a community of practice, consisting of a community of researchers who seek to collectively advance knowledge within their domains. Researchers who collaborate to address a research problem are collectively engaged in a unique cultural context that is mediated by practices historically situated in norms and values of the scientific community. We acknowledge that the roles and responsibilities of research communities vary across disciplines and individual research groups. Therefore, enculturation into the research community is a balance between learning broad practices within the domain and navigating the unique social dynamics and culture of the local community.

Student navigation through the research community of practice

As they embark on their first research experiences, undergraduates are legitimate peripheral participants who begin on the periphery of the community as newcomers who have limited access to the knowledge, skills, and practices. Students are introduced to the practices through the expertise of their mentors or more experienced peers, gradually gaining a more nuanced understanding of the values, norms, and daily activities of the community. Learning is focused on the acquisition of authentic research practice rather than the transmission of abstract content knowledge that is divorced from practice (John & Creighton, 2013).

However, many students are outsiders to the research community and have few navigational resources to even enter on the periphery. This barrier to entry is especially prevalent for students who are from a group historically under-represented in STEM, including transfer students. For example, the cultural knowledge that underrepresented students receive from their families is not always appreciated in traditional higher education settings, and these students may not be privy to the unique system of socially reproduced cultural knowledge present in the scientific research community (Dika & D'Amico, 2016). Many students may also have racialized or gendered experiences and may be affected by implicit biases in their interactions with individuals in power in the research community (Carlone & Johnson, 2007; Castro & Collins, 2021). Students may be less inclined to choose a research-related career or persist in their STEM major when they are not provided with ample opportunities to be socially and intellectually enculturated into the practices of the research community and if they feel that their sociocultural identities are not welcomed or valued (Thiry et al., 2012).

Even students who successfully cross the barrier of moving from the outside to the periphery of the research community may not experience stability as the shifting participation within a community of practice is not a linear process. Interactions with different members can shift one's position either further from or closer to the center where experts inhabit. An individual's trajectory is dependent on the joint activities and interpersonal experiences within the sociocultural space, and learning therefore depends on the structures, supports, and agency of the individual members (Quan et al., 2018). As students are enculturated into the research community and the sociocultural context in which research practices occur, they are provided with the autonomy and agency to participate in increasingly difficult tasks (Gardner et al., 2015; Sadler & McKinney, 2010). Through legitimate peripheral participation, they progress from being newcomers to developing professional identities and feeling more established in their membership within the community of scholars. However, continued support and mentorship is essential to sustain this inbound trajectory as students navigate new research experiences and interpersonal interactions in their respective professional pathways.

Summer bridge program as proposed vehicle of enculturation into the research community of practice

Our objective is to examine transfer students' enculturation into the research community of practice during the summer bridge program, followed by an examination of the impacts that this enculturation had on their longer-term participation in research experiences and pursuit of career pathways and graduate opportunities in STEM. Engagement in the joint enterprise of research practices through legitimate peripheral participation is a central goal of the summer bridge program (Figure 1). The summer bridge program strives to reduce the barrier that transfer students face to pursue research opportunities by targeting students who typically do not have access to the resources to even enter the periphery and initiate their inbound trajectories toward the centralized practices of the research community.

The summer bridge program aimed to legitimize students' participation in the research community by providing participants with resources and experiences that would enhance their professional research skills and enculturate them into the community. This participation was facilitated by faculty mentors, experts within the research community of practice that help increase the authenticity of the learning and guide newcomers' movement from the periphery to a more central role in the community (Ceyhan & Tillotson, 2020). Research

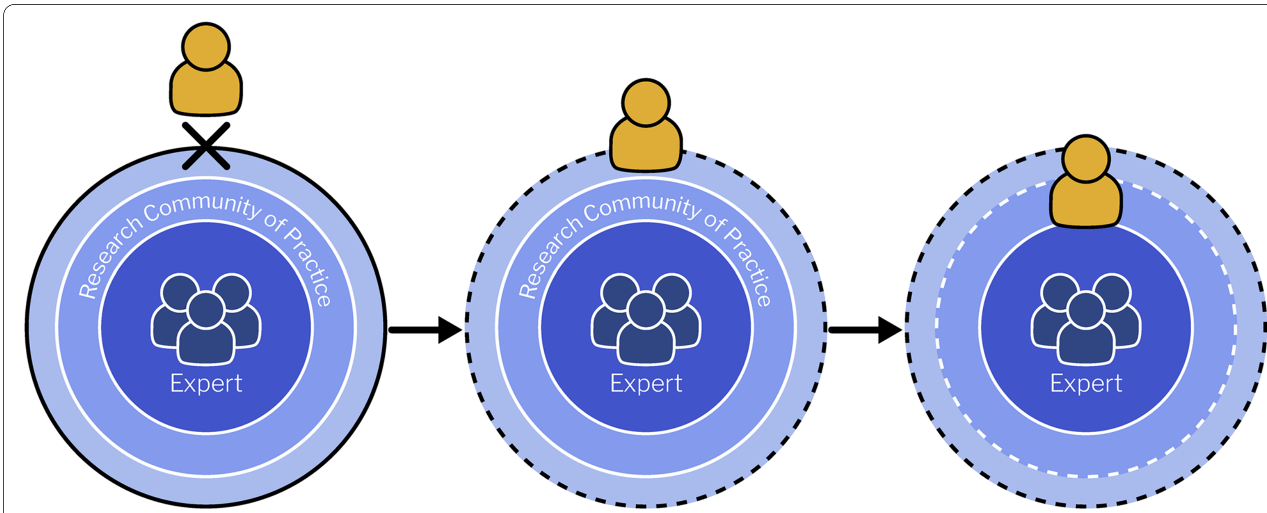

Figure 1 The scientific research community is a community of practice with unique cultural norms and values. Many transfer students do not have access to the research community upon entry into the university (left). The summer bridge program strives to position transfer students on the periphery (middle) and support their inbound trajectory toward the center inhabited by expert scientists and researchers (right).

experiences involve social or cultural interaction with mentors who promote students' intellectual development in the authentic or simulated activities of the community.

The resources, mentorship, and social capital that students acquire would ideally provide them with a sense of legitimacy in the shared practices of the research community and allow them to leverage their newly acquired skill sets in their academic coursework and subsequent research opportunities. Therefore, outcome measures in the summer bridge program assessed the extent to which participating students perceived an increased sense of self-efficacy in knowledge and skills central to becoming legitimate members in the research community of practice. The program's role as a platform for enculturating students into the research community was further examined by tracking students' longer-term academic and professional trajectories, including their subsequent participation in undergraduate research experiences, matriculation into Ph.D. programs, and occupational attainment in STEM.

Methods

In this study, we describe the summer bridge program as a case study to examine a contemporary phenomenon, in this instance, a research-integrated summer bridge program for transfer students, within the localized context that it was implemented (Yin, 2003). It was hypothesized that students would benefit from the strength of the local research community as well as the collective knowledge of the program faculty in implementing high-impact practices that support mentorship and inclusion for diverse transfer students. We rationalized that the summer bridge program would serve as an ideal study site for studying transfer students' trajectories and outcomes in STEM because of its dual role in supporting students through a critical academic transition and promoting early inclusion in the scientific research community.

Study context

This study took place at a public university in the western United States, described by the Carnegie Classification of Institutions of Higher Education in the category of "very high research activity" and with a 4-year, full-time, more selective, and higher transfer-in undergraduate profile (McCormick & Zhao, 2005). Approximately one-third (33%) of undergraduates admitted to this university each year are transfer students from local community colleges that serve underrepresented students, with over 40% pursuing majors in STEM. The transfer students at the university primarily matriculate from local community colleges. The university has one of the highest national and global rankings in STEM research across many disciplines, many faculty conducting research in biological sciences, and a substantial level of federal research dollars invested in campus research. Given these characteristics, we reason that this university is an ideal study site for recruiting and training diverse transfer students and propelling them into STEM graduate programs.

The summer bridge program spanned three summer academic breaks (2015, 2016, and 2017), each with a different cohort of students who were entering their first term at the university. The first iteration of the program was eight weeks in duration while the second and third iterations were six weeks. The program was designed to provide entering transfer students with skills that would ultimately help them join a research lab: hands-on experience learning laboratory techniques and protocols, journal club discussions of primary literature, lectures from varied faculty to learn about the broad range of opportunities for doing research, periodic discussions about the practice of scientific research, required training in lab safety and lab etiquette, grant proposal writing and presentations of results at conferences, and Graduate Record Examination (GRE) training. The program culminated with a 2-week period in which students, in pairs, designed an experiment with program faculty oversight, obtained preliminary results, and presented them to the group. Lastly, the students attended a university-sponsored research conference, where they listened to talks by more advanced undergraduates already working in faculty labs.

The program consisted of a series of one to two week modules, each designed and run by a different faculty member associated with the program and based on research methods used in their labs (Additional file 1: Appendix 1). For example, the first module used the leech nervous system to teach basics of intracellular electrophysiology and single neuron anatomy; the second module exposed students to various molecular and biochemical techniques that are used to study neuron and synapse function; and the third module introduced students to basic methods in bioinformatics and concepts in utilizing biology data resources to augment experimental research. Each year, faculty were brought in to teach one or two modules. The last module was devoted to student-designed projects that generally involved using methods from more than one of the earlier modules, though they could learn and bring in additional experimental tools.

Each day was structured such that mornings consisted of lectures by program or invited faculty, discussions of the previous days' exercises and results, and external activities that brought the students together with students engaged in other summer STEM programs to learn about requirements and other demands of university life and career planning. Afternoons were spent conducting experiments in the lab or exercises on-line. In the last afternoon session for each module, the students presented the results of their work. There were also occasional social gatherings in the late afternoon or early evening to promote networking and peer support.

Following the summer research experience, the program faculty regularly coordinated and facilitated meetings and informal social events with participants, with about 75% of the students in attendance. Because the program prepared students for undergraduate research opportunities, many participants had gained new mentorship in a faculty laboratory following the program. At this institution, students typically obtain positions in faculty laboratories by directly contacting and arranging an independent research experience with the faculty. While this process was not coordinated directly by the program, the program faculty remained accessible for advising and mentorship as the students sought out new research opportunities. They also supported the participants' other academic and professional endeavors for the remainder of their time at the university through ad hoc meetings and email communications.

Recruitment and admissions

As part of the recruitment process, informational flyers were sent by a mailing list to community colleges across the United States. Core faculty in the program also hosted an informational session during a university-sponsored recruitment event for transfer students. Applications were completed online, and all applicants submitted a letter of recommendation from a previous or current science instructor who could speak to their ability to succeed in a summer research program.

Prerequisites for admission included the completion of foundational biology coursework in community college and an interest in pursuing graduate and professional school opportunities in research. Students from groups underrepresented in STEM were particularly encouraged to apply. About 50 applications were received for each summer, and funding allowed for acceptance of approximately 15-25% of applications per cohort. Eight transfer students were selected to participate in the first cohort, ten in the second, and fourteen in the third, equating to a study population of 32 total students.

Sixteen different in-state and two out-of-state community colleges were represented by our participant sample. While the student's location was not a selection criterion, the program required students to be present on campus on weekdays, thus likely resulting in more local applications. The participants were diverse in gender, first-generation status, and race and ethnicity, with a majority of students in at least one group that is historically and/or currently underrepresented in STEM, which we define as women, first-generation students, and non-White or non-Asian students (Table 1).

Participants were asked to report their current field of study in the program application and again during a post-program survey. Although the program had a neurobiology focus, pursuing a major in biological sciences was not required as long as students demonstrated interest in pursuing graduate studies in STEM and majored in a STEM field. Nevertheless, most students entering the program majored in biological sciences (Table 1). In the end, some students graduated with a major outside of biological sciences and all but one remained in a STEM discipline.

Table 1 Aggregate demographics of study participants (n=32). First generation students are designated as neither parent nor guardian having received a four-year university degree in the United States

Demographics	Number	Percentage
Gender		
Women	18	56%
Men	13	41%
Transgender Man	1	3%
College generation status		
First generation	25	78%
Continuing generation	7	22%
Race or ethnicity		
Hispanic or Latinx	10	31%
Middle Eastern	6	19%
Asian	5	16%
Asian and White	3	9%
Hispanic or Latinx and White	3	9%
White	3	9%
African American or Black	1	3%
Unknown	1	3%
Field of study (at time of program)		
Biological sciences	25	78%
Cognitive science	3	9%
Engineering or computer science	2	6%
Psychology	1	3%
Pharmaceutical sciences	1	3%
Field of study (at time of graduation)		
Biological sciences	15	47%
Cognitive science	7	22%
Engineering or computer science	4	13%
Psychology	2	6%
Physical sciences	1	3%
Health sciences	1	3%
Mathematics	1	3%
Economics	1	3%

Mixed methods research approach

This study applies a mixed-methods approach where the outcomes of the program are presented from the perspective of the participating students through a combination of quantitative and qualitative measures. We used a concurrent triangulation design for our mixed methods approach, where quantitative and qualitative data collection and analysis is done separately but merged afterward (Warfa, 2016). Although some concurrent triangulation studies prioritize one data source over another when drawing conclusions, we gave equal footing to both the quantitative and qualitative data sources. We reasoned that the triangulation of both data sources could offer unique insights into different dimensions of the students' experiences while also having the potential to converge or offer complementary insights.

Quantitative instruments and analysis

A survey was administered in the first week of the program (pre-summer) and again during the last week of the program (post-summer) to measure short-term changes in multiple psychosocial dimensions of the students' research experiences (Additional file 1: Appendix 2).

The quantitative analysis used established survey instruments for students to rate their perceptions of experience in research skills, knowledge of navigational processes in STEM careers and graduate school, and interest in continuing in a science major and career pathway. We used a modified version of the Summer Undergraduate Research Experience (SURE III) survey (Lopatto, 2004; Lopatto, 2007 and Lopatto, 2008) to measure research knowledge and research self-efficacy (Additional file 1: Table A-1). To capture the pre-summer baseline, we used scales on pre- and post-summer knowledge (1 = very uninformed, 6 = very informed) and self-efficacy (1 = very inexperienced, 6 = very experienced) instead of the original scale on post-summer self-reported learning gains (1 = no gain, 5 = very large gain). The scales were also modified from five points to six points, eliminating the ambiguous mid-point option in the equivalent five-point scales, which could be interpreted as neutral or undecided, two similar but distinct constructs (Armstrong, 1987; Guy & Norvell, 1977; Komorita, 1963). The modifications resulted in Cronbach's alpha values of 0.87 and 0.93 respectively for the research knowledge and research self-efficacy items (Additional file 1: Table A-1). While there are no universal guidelines for interpreting Cronbach's alpha values, these values fall within the good to excellent range of reliability (Taber, 2018). Analogous modifications were previously determined to retain high internal consistency and reliability (Lo & Le, 2021; Mordacq et al., 2017). Students also indicated their intentions to continue their scientific training through coursework, laboratory experiences, and career pathways using previously developed items (Lo et al., 2014). The items for this dimension had a Cronbach's alpha of 0.95, indicating excellent reliability (Taber, 2018).

Because it was hypothesized that the program could help students become more confident in leveraging relationships when pursuing academic resources, students were asked questions related to motivation for resource management, where they rated "help seeking" items adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, 1991). The scale was modified from a seven-point Likert scale to a six-point Likert-like scale (1 = strongly disagree, 6 = strongly agree) to eliminate the ambiguous mid-point option. The modifications resulted in a Cronbach's alpha value of 0.61 (Additional file 1: Table A-1), which is a moderate but often deemed as acceptable value for reliability (Nunnally & Bernstein, 1994; Taber, 2018).

Ratings of community support were collected in the post-program survey to determine the extent to which students perceived a sense of belonging in the program community, which is another affective psychosocial construct often triangulated with ratings of self-efficacy (Trujillo & Tanner, 2014). Participants' sense of community was measured using a modified version of the Classroom and School Community Inventory (CSCI) (Rovai et al., 2004). The instrument has two dimensions: learning support and social support (Additional file 1: Table A-1). Items that originally referred to "the course" or "the school" were changed to "the program" to account for the study context being a summer bridge program. The scale was modified from a standard five-point Likert scale to a six-point Likert-like scale (1 = strongly disagree, 6 = strongly agree). The modifications resulted in Cronbach's alpha values of 0.84 and 0.92, respectively, for learning support and social support items (Additional file 1: Table A-1), indicating good to excellent reliability (Taber, 2018). As these items measure participants' sense of community in relation to the summer bridge program, this survey was administered only at the end of the summer.

Finally, to capture outcomes beyond the summer, a survey was administered in 2020, 3-5 years after the initial summer bridge program for the three cohorts (program years 2015-2017). The survey asked participants about their engagement with independent research as undergraduate students, what year they completed or planned to complete their undergraduate degrees, their current post-graduate positions (if applicable), and future graduate school and career goals.

Statistical analysis

Descriptive statistics were calculated for the survey responses, and frequency distributions are provided for each item (Additional file 1: Appendix 3). Pre- and post-summer responses were compared using a paired t-test, and the Holm-Bonferroni correction was used to correct for multiple comparisons (Holm, 1979; Shaffer, 1995). Effect sizes were calculated using Cohen's d, which is defined as the difference between the pre- and post-program means normalized to the standard deviation from the pre-program data (Maher et al., 2013). Because of the limited sample size, we were not able to re-validate the survey instruments using factor analysis (Knekta et al., 2019); instead, we opted to confirm internal consistency and reliability using Cronbach's alpha (Cronbach, 1951; Tavakol & Dennick, 2011). All statistical analyses were performed in JMP Pro Version 13.0-16.0 and Microsoft Excel.

Qualitative analytical approach

To gain qualitative analytical insights into the specific benefits of the program, semi-structured interviews were conducted to provide students with an opportunity to articulate their program experiences and perceived outcomes from participation. While the survey measures focused primarily on summarizing students' attainment in research skills, knowledge, and opportunities, the interviews were intended to provide students with an additional platform to broadly reflect on how the summer bridge program affected their academic, social, and professional development as they neared the end of their undergraduate studies. Because participants had accumulated most of their academic and research experiences at the time of the interview, they could retrospectively reflect on the benefits and drawbacks from participating in the program, thereby giving formative feedback on how the program influenced their trajectories in STEM as they progressed through their undergraduate education.

Interview recruitment and protocol

Participants were invited to participate in an in-person interview to provide formative feedback on their experiences in the program. The participants were interviewed about two years after the summer bridge program, near their target graduation dates, with the intention that the participants would be able to reflect more comprehensively on how the program may have had longer term impacts on their university experiences and development as students and researchers. Data collection spanned three years in total to interview participants from all three cohorts of students, and a total of 29 students across the three cohorts agreed to participate.

A semi-structured interview protocol was implemented as part of a larger study to examine the participants' university, community college, and research experiences. For the questions analyzed in this study, the interview protocol prompted participants to retrospectively articulate the benefits and drawbacks of participating in the summer bridge program, the extent to which they perceived gains in the academic, professional, and social dimensions of their development, their ability to capitalize on campus resources as a result of participating in the program, and suggestions for how the program could be improved in future iterations (Additional file 1: Appendix 4).

The interviews were conducted by two graduate students who had no previous involvement in the program. The limited prior interactions with these interviewers could have affected the participants' willingness and comfort to share their responses. To encourage the participants to think and talk freely, the interviewers intentionally did not react outwardly to participants' responses (disessa, A. A., 2007). Although the participants were given the option to end the interview at any point if they felt uncomfortable, all had completed the full interview.

Qualitative data analysis

The average length of the full interview for the larger study was approximately 34 minutes, and interviews were transcribed semi-verbatim by a professional transcription service. Interview transcripts were analyzed following qualitative coding methodologies detailed by Saldaña (2015). Responses to each interview question were annotated with brief notes and labels that described salient trends and analytical insights. Interview questions that asked participants about benefits for different dimensions of their development began with a close-ended question that prompted participants to indicate whether they benefited in that dimension. Each response was coded as "directly benefited" if the participant articulated direct benefits, "partially or indirectly benefited" if the participant indicated that they only somewhat benefited or if they perceived that the benefit was indirect, and "did not benefit" if the participant did not feel that they benefited in that dimension (Table 4). In each dimension, only one of these codes was applied per participant.

Inductive analytical codes and memos were generated to summarize the range of benefits or drawbacks that the participants collectively experienced as a result of participating in the summer bridge program. The inductive codes were then applied to individual participant responses. The frequencies of these codes were summed across the entire interview sample for each dimension, and codes with frequencies greater than one are presented in Tables 3, 5, and 6. In this stage of the analysis, multiple codes could be applied to a single interview transcript, as some participants articulated multiple benefits or drawbacks when reflecting on their experience in this program. Therefore, the sum of the code frequencies had the potential to exceed the number of participants in the sample.

The research team regularly discussed and critiqued the analytical memos and in vivo codes. A subset of interviews (~40%) were coded by two researchers (ALZ and SML) for the larger study. The two researchers achieved substantial to almost perfect agreement, with an interrater agreement of 87.5% and a Cohen's kappa of 0.82 (Cohen, 1960; Landis & Koch, 1977). Given the substantial agreement, one researcher (ALZ) proceeded with coding all the interview responses. Regular meetings between the two coders confirmed that the interpretations of the interview responses were consistent. Codes and excerpts were regularly presented to a community of discipline-based education researchers and STEM researchers in research meetings. This additional feedback verified that the claims were grounded in the data and that the codes and excerpts appropriately summarized the formative feedback provided by the participant sample.

Positionality of authors

We include statements of positionality to contextualize each author's role in the program and relationships to the program participants, as our roles influence how we conduct the research and interpret its outcomes (Rowe, 2014). ALZ was a graduate student who had no prior interactions with the participants or involvement with the program. ALJ was hired as a professor in neurobiology after the summer bridge program and during the follow-up interviews with students and therefore was not involved in the program. BLB, TG, and ERM are professors who participated directly in creating and running the summer program (with ERM serving as the program director), and thus interacted extensively with the participants throughout their undergraduate education at the university. DA is a dean and director of undergraduate academic enrichment programs who occasionally interacted with participants at social events and facilitated collaborations between the program community and other campus programs and resources. SML is a professor who occasionally attended program social events and presented a faculty research talk to one of the cohorts, but otherwise had no direct connections. ALZ and SML had community college experience when they were undergraduate students, and BLB was a transfer student who matriculated from one of the local community colleges attended by some of the participants. We acknowledge the potential for some authors to have biased perspectives toward the participants' experiences based on interpersonal relationships developed during the program. However, the authors' diverse educational backgrounds, professional experiences, and degrees of involvement in the program allowed contextualization of the participants' experiences while providing enriched and diverse interpretations of the data.

Results

Students demonstrated short-term gains in self-efficacy and knowledge of career pathways

The summer bridge program aimed to enculturate students into the practices of the STEM research community by helping them adopt skill sets and knowledge that are broadly applicable across different STEM domains. Upon entry into the program, participants reported a mean skill rating of 3.54 ± 0.74 across the 20 survey items related to self-efficacy in research skills, overall indicating that they felt somewhat inexperienced to somewhat experienced in many of these common research practices (Table 2). However, students reported significant gains ($p < 0.05$) in research self-efficacy in six out of 20 these survey items with effect sizes ranging from 0.43 to 1.27, as measured by Cohen's d, and an overall mean skill rating of 4.27 ± 0.64 (Additional file 1: Table A-2; Additional file 1: Table A-3). Seventeen of the 20 items had mean

Table 2 Summary statistics for each survey subscale. Pre-program and post-program survey scores are compared for each subscale (n=24 responses). Social support and learning support subscales were only measured in the post-program survey. Descriptive statistics (average ± standard deviation), p-values, and effect size (ES, calculated as Cohen's d) for each scale are provided. *** $p < 0.001$; ****$p<.0001$ *n.s.* Not significant

Subscale	Sample Item	Pre-program	Post-program	P	ES
Research self-efficacy	Read and understand scientific papers	3.54 ± 0.74	4.27 ± 0.64	***	0.98
Research knowledge	How scientific knowledge is constructed	3.70 ± 0.79	4.83 ± 0.59	****	1.43
Science career	I plan to seek a job where I would use my science knowledge.	5.63 ± 0.86	5.75 ± 0.38	n.s.	0.14
Help seeking	When I cannot understand the material in class, I ask another student in the same course to help.	4.48 ± 0.78	4.41 ± 0.78	n.s.	-0.09
Social support	I feel that students in the program care about each other.	NA	5.39 ± 0.71	NA	NA
Learning support	I feel that the program results in substantial learning.	NA	5.63 ± 0.47	NA	NA

ratings greater than 4.00 in the post-program measure, indicating that participants, on average, perceived that they were at least somewhat experienced in most of the research skills by the end of the program.

Similarly, in their ratings of items related to knowledge of the work done by scientists and navigation of career pathways and graduate opportunities, participants reported a mean rating of 3.70 ± 0.87 across the six items, indicating that they felt somewhat uninformed to somewhat informed about these processes. In all six items, students reported significant gains, with effect sizes ranging from 0.57 to 1.51 and a mean rating of 4.83 ± 0.59, indicating that participants overall felt informed about knowledge related to navigating a scientific career pathway by the end of the program (Table 2; Additional file 1: Table A-4; Additional file 1: Table A-5).

Two survey dimensions were not significantly different in the pre-and post- program measures (Table 2; Additional file 1: Table A-6; Additional file 1: Table A-7). Participants reported a nearly identical sense of motivation for seeking help from others when struggling with concepts or material in the pre- and post- program measures (4.48 ± 0.78 for pre-program and 4.41± 0.78 for post-program). Likewise, their motivation for pursuing a science career pathway was near the maximum rating in both measures and thus not significantly different (5.63 ± 0.86 for pre-program and 5.75 ± 0.38 for post-program).

Finally, the sense of belonging metric was measured across two community measures derived from the CSCI: social support, which relates to how connected students feel with others in the program, and learning support, which relates to the extent to which the students feel that their learning needs are met. Overall, participants reported very strong social and learning support in the program, with an average rating of 5.39 ± 0.71 and 5.63 ± 0.47, respectively, on a six-point Likert-like scale (Table 2; Additional file 1: Table A-8; Additional file 1: Table A-9).

Students continued to engage in research after the summer program

Because students in the post-program surveys reported statistically significant increases or increases with moderate effect sizes in their self-efficacy in research skills and knowledge, we sought to document students' trajectories in research opportunities and their career pathways following the program to further understand how the program may have served as a platform for longer-term persistence in STEM majors and the pursuit of new research opportunities. All 32 students who participated in the three cohorts responded to the online survey administered in 2020. At this time, all students had graduated or were completing their final term at the university. Following the summer bridge program, 30 out of 32 participants secured positions in faculty laboratories. Because there was no formal laboratory application process facilitated by the program, there was no direct connection between the laboratories that students joined after the program and faculty who led the modules. Nonetheless, six students had participated in research in one of the program faculty's laboratories and approximately half of the remaining students joined a laboratory that presented a guest lecture during the summer program. Collectively, the students completed a median of four academic quarters of independent research during their undergraduate education, indicating substantial research engagement following the program. Of the participants who reported their current career trajectories, 11 were employed in the research industry, 10 were enrolled in graduate programs in a STEM discipline, four were in medical and health professions, and two were completing their undergraduate degrees at the time of the survey. Only one student had a final degree or career goal that was outside of a STEM discipline.

Participants reported many academic, social, and professional development impacts of the program

Participants also provided formative feedback of their experiences in the summer bridge program by articulating how the program did or did not support various dimensions of their development in their academic careers. When prompted to state whether they benefited from the program, all 29 interview participants were able to recall specific benefits that they felt were meaningful to their development as students and researchers. The most common benefits described by the participants include mentorship and networking opportunities from faculty, securing research opportunities, developing transferable skills and research interests, receiving guidance during the transition from community college to university, gaining knowledge applicable to coursework, and growing personally and professionally (Table 3).

The participants then were prompted to specify whether they benefited in different dimensions of their development as a student because of the summer bridge program (Table 4). Academically, 25 of the 29 participants articulated that they had gained transferable knowledge or skills from the program, including relevant laboratory skills and techniques, the ability to read research papers, relevant content knowledge, enhanced reasoning skills, and enhanced time management skills and work ethic. Although the content may not have been directly relevant to their field of study, some participants articulated that learning about the diversity of research was still beneficial for their academic development. As one participant stated:

Table 3 Benefits of participating in the summer bridge program. In an interview to provide formative feedback on the program**,** participants articulated the benefits they obtained. Coded benefits are in order from highest to lowest frequency, and sample responses are provided for each code. Because many participants described multiple benefits, the number of coded segments (n=65) exceeds the number of participants in the sample (n=29)

Coded benefits (frequency)	Sample response
Mentorship and Networking (20)	"The biggest reason is definitely networking with the different professors when we are introduced to all sorts of different faculty. That was huge because we got exposed to different kinds of lab settings and you kind of knew what you liked and what you didn't like."
Future research opportunities (14)	"I like transition programs and research programs in general because. It helps me be open to more opportunities. So, after the [summer bridge] program, I was able to get into McNair and I've been in over like five conferences and I just got [a scholarship], so I'm excited. So, it just opens doors I think for more opportunity."
Transferable Research Skills (9)	"I was able to apply, and talking to my mentor now, she said [she] wouldn't have accepted [me] if I wouldn't have gotten everything I learned during the [summer bridge] program…like the pipetting and the culturing. I feel like I learned a lot during the program."
Easier community college to university transition (8)	"Navigating through the campus, connecting with people, transportation and being able to find the closest parking to my classes and stuff. So, when I started the first quarter at [the university], I wasn't lost like everyone else, because I saw other students who were like my classmates in community college coming here being lost and frustrated because they couldn't get to classes on time because they couldn't find their classes. So, that helped me a lot, like, relax and be more comfortable being at the new school."
Enhanced research interests (6)	"I guess expanding your scientific literacy. Like there is so much I learned, so [many] types of research going on here that I had no idea even existed as far as like research with bacteria, genetics, and all that stuff. So, it was a good survey of all these different kinds of research going on at [the university]."
Content knowledge applicable to courses (3)	"Also, the project that I did, my research project that I did, at the end of the [summer bridge] program. I used that, for example, for an assignment for my molecular biology class which I just finished because the professor asked us to write a mini-grant as an assignment and that was almost 40% of the grade in that class. And we were supposed to do something like, a mini research project, and use all the methods and everything we would need to write a mini-grant. So, because I didn't publish anything about my small research that I did at the end of the [summer bridge] program, I used that to write the mini-grant assignment and I got 59/60 for that assignment."
Healthy challenge (3)	"I think that it was to date one of the more difficult things that I've done at [the university], and I think that it set a threshold for me to judge other things by, and I think that [I learned about] lab culture, how to read and present on papers, [and] sorts of questions to ask."
Personal growth (2)	"It definitely opened my eyes to what I could do. It definitely put research in one of those options for me to that I could, you know, pursue for my future."

Table 4 Frequency of participants who benefitted in different aspects of their development because of the summer bridge program. Participants (n=29) were prompted to indicate whether the program was beneficial for developing academic skills and knowledge, connecting with faculty and researchers, connecting with other students, and navigating the campus and resources. Participant responses were coded as either having directly benefited, partially or indirectly benefited, or having not benefited for each dimension

Dimension of development	Directly benefited	Partially or indirectly benefited	Did not benefit
Academic skills and knowledge	23	2	4
Professional connection with faculty and researchers	21	4	4
Social integration with other students	14	5	9
Navigating campus and resources	17	6	5

I learned more about the diversity of research. And it was definitely knowledge that was totally out of my comfort zone because it was mostly [bio] Physics and stuff like that, which I always struggled with. I'm really glad that I kind of struggled through it because I feel like I did learn some stuff and that knowledge kind of stuck with me.

Because some participants had changed their major from biological sciences to another STEM discipline or were majoring in a field outside of biological sciences when entering the program, three of the four participants who did not perceive that they benefitted academically stated that the intensive focus on biology content in the program simply did not transfer to their academic coursework. For example, one participant said:

It was very bio heavy and there haven't been a lot of biology courses that I needed to take. I had *already taken most of them by the time I got there, so, not to say that I didn't learn a lot, but just I don't think it applied a lot to the academics that I've pursued later.*

Professionally, 25 out of the 29 participants perceived that they had at least partially felt more connected with faculty and researchers on campus as a result of the program. Participants who perceived they only partially or indirectly benefited felt they still had the agency to build connections due to their increased confidence when interacting with faculty. As one participant stated:

I think if I were in the bio fields, that would be the case because we would have professors come in and present on their research once a week, or even more than once a week sometimes and I thought that was very beneficial, so we got to realize kind of just general things like, "oh they're regular people", you know, they're really easy to talk to for the most part. So not directly. But it did give me the, it raised my level of comfort when talking with professors. And it gave me the confidence to reach out and treat professors differently than I might have in the past.

Some participants believed that their increased connection with faculty was rooted in their broader understanding of faculty research done across campus rather than a direct personal connection. For example:

When I just refer to classes and see who [the professor is] that's giving that class, it could be a professor that I already met or listened to during the [summer bridge] program. So, I would know what their research is about and so I kind of have an idea of what the class is going to be about.

Socially, 14 out of 28 participants (one was not asked) articulated that they felt more socially integrated with other students on campus because of the summer bridge program. As described by one participant:

It gave me the comfort to be able to go out and socialize with new students and know that it's not entirely intimidating to meet new people that go to [the university], because I think I kind of had imposter syndrome when I first came in [laughter]. So, I was like, "Oh, my god. Everyone here [are] like little Einsteins. I can't talk to them." But they're very cool. They're just very much like me. And so, it made it really break down my stereotypes about what [the university] would be like, which was very, very important. I don't think I would have done well at all had I not done the [summer bridge] program.

An additional 5 out of the 28 participants had stated that they felt that they partially benefitted in their social development, but several articulated this was primarily through social integration with students in the program and related programs rather than other students on campus. For example:

I mean there's always the familiar face, right? From the summer research programs because we would all go to the events together. Not just from the [summer bridge] program, like the McNair program, the [university] scholars program. So, yeah. Seeing familiar faces like "oh hey, like I know you." I don't typically actively seek out companionship I guess amongst the people. But definitely among, among the [summer bridge program] people I have, like whenever we see each other, we stop and catch up.

Finally, in learning to navigate their new university campus and resources available, 17 participants had perceived that the summer bridge program was directly useful in helping them develop this navigational capital. One participant who benefited stated:

I learned that the academic enrichment programs [are] a really great resource for students. Before I got into the [summer bridge] program, I didn't know such programs existed at any campus. And yes, anytime I have a question on a program or anything, I would go to them and ask them.

An additional 6 participants posited that the program was indirectly beneficial, as they gained knowledge about the resources available, but did not choose to actively seek or use them. For example:

I think part of why, the reason why, I had trouble my first year was not from the lack of the resources that were provided for me from [the summer bridge program], but I think it was more like me not actually going.

One participant from the first cohort of the program articulated that she felt the program did not sufficiently orient students toward campus resources. She articulated that many summer programs sponsor primarily continuing students, and therefore the structure of these programs typically do not account for helping students with navigating resources. She perceived that the summer bridge program also had this deficiency in the structure.

I don't think so. I think that was lacking. (…) I met the new [program participants] and I asked the [program coordinator] if I can do a quick 10-minute lecture on student resources and he was like, "yeah, sure". So, I just really hope that, you know, they try to

> *implement that more, but I understand it's a super intensive program(...). But the issue with that is that like all the [summer programs], they're all like continuing students, the majority of those. And I don't think they well prepare students, transfer students who are basically, they're completely new students to the campus and I don't think they have thought that through. Like we might need more resources than the average other programs.*

This participant later volunteered as a guest speaker for future cohorts of the program. In her informational sessions, she offered more direct advice to students about how to navigate campus resources and academic enrichment programs. Several participants in these subsequent cohorts articulated that having this additional information session was immensely beneficial. For example, one participant in a later cohort stated:

> *The first week that we were in the [summer bridge] program, we had another student that was volunteering to help the program and everything, and she came and told us about all these different resources. And because of her, I did get into [another program] (...). I learned how to navigate the campus, which is a little overwhelming when you first get here.*

Drawbacks and challenges

As part of their formative feedback in the interview participants were prompted to explicitly state any drawbacks from the program and to offer their feedback as to what they think the program could do to improve the experience for future students. The feedback provided by the students was overwhelmingly positive, as 17 out of the 29 interview participants were not able to identify any drawbacks in their experience at all. Nearly all drawbacks that the remaining participants articulated related to the intensity and time commitment of the program, including the limited time to devote to other commitments, struggles with commuting and parking, the heavy workload, experiencing increased stress during the program, and the challenge of the subject matter content (Table 5).

Finally, participants described suggestions to improve future iterations of the program and alleviating the time intensity of the program was the most common suggestion (Table 6). Many participants had felt that the amount of content and project work required to complete in the program was compacted into too short of a time span. However, they also acknowledged that the time intensity was reflective of the professional world. For example:

> *I know that they're only trying to expose us to kind of real-life lab settings where you can spend a whole day or just countless hours in a lab. But I feel like the transition for many of us, just staying in a lab for hours trying to get the results that we want and possibly not succeeding, that really sucked. Because some days just lasted so long, and we just couldn't wait to get out of there. But I mean, that's also real life.*

Other repeated suggestions for improving the program included increased time for exploring personal research and professional interests, more focus on alleviating stress and promoting self-care, increased exploration of

Table 5 Drawbacks of participating in the summer bridge program. Coded drawbacks are in order from highest to lowest frequency, and sample responses are provided for each code. Seventeen out of 29 participants did not articulate any drawbacks. Some of the other twelve participants described multiple drawbacks, resulting in a total of 22 coded segments

Coded drawbacks (frequency)	Sample response(s)
Time Intensive (7)	"Maybe timing. It was just a tiring program, a very intense program in terms of time. It took us from 8:00 in the morning to like maybe sometimes at six. We were not living on campus, so that made it even harder.
Commute/Parking (6)	"If you're commuting, that took another couple of hours. So, you definitely can't have anything else going on in your life. Like, you need to be able to dedicate all your time to doing it."
Workload (4)	"We have our lives, and we just can't drop everything. I just feel like I really wish [the summer bridge program] would have taken into account that we're completely new to this environment and given us time in the program to do homework. Because I had done a previous program at [another university], a research program, and we did that. We had that extra time to do research, I mean to do our homework and that was implemented into the program."
Stress (3)	"And we had really short lunch breaks or really short breaks. I was very stressed out at that time, and that's something that I wish they would keep in mind, like the health of the student, or just like we're new to [the university] and it's a very stressful situation, for me at least."
Advanced Content (2)	"But in in my year, we had to attend talks for I think Master's and Ph.D. students. Those were very high level compared to our level as students coming from community college. So, we would go and sit and attend the talks, but we couldn't like understand everything that was being said there. But, it was good in a way because I got to know professors that I would see in the campus and know like, oh, this is this professor, this professor does that, so I used that to learn about what research experiences, what research labs are doing here, but I couldn't understand the details of the talks I was attending."

Table 6 Participant suggestions for improving future iterations of the summer bridge program. The 29 interview participants were asked if they had suggestions for improving the program, and all except two provided specific suggestions. Coded suggestions are in order from highest to lowest frequency, and sample responses are provided for each code. Codes with frequency greater than one are shown (34 total coded segments)

Suggested improvement (frequency)	Sample response
Less time intensive (17)	"Maybe if we had a little bit longer honestly. Towards, I know toward the sixth week, I was getting a little bit tired because there was a lot of work, right? Wake up early and you had to sit in traffic going all the way home. Traffic here, that was probably the worst part of it but, it was what really tire out. Actually being here and doing the work was great. And I kind of wish we had a little bit longer to do it because everything felt like a little bit rushed, especially the ending, like, personal projects. If we had a little bit more time, I think that would have been better. Maybe get a little better fundamental understanding of things. So, if anything, maybe a little bit longer time to either slow down the pace, like half a step or, who knows, introduce more modules."
Increased exploration of personal interests (4)	"Because I know for the [summer bridge program], when I did [it], there was a little bit a little part of it that involves some bioinformatics work with one of the professors and it so happens that that was my favorite part. And because of that, I planned on switching into bioinformatics and then I realized that I am more in computer science and that gave me the transition. Who knows, if I had never had the two weeks of bioinformatics work, I would have never realized that I am actually more fond of the, you know, the technological, you know, techniques or skills that you can develop in order to help people of different fields including biology. And so, giving people more experiences from diverse backgrounds might be useful."
Less stressful (4)	"I remember being extremely stressed out, so just like the acknowledg[ment] of the students' self-care and they need to take care of themselves too and it's completely new. I mean how important is the researcher or like if they're like not having any sleep? So it's like that whole balance thing, I think it needs more balance."
More social bonding (3)	"I would say maybe having the people in the cohort getting to know each other. Maybe like social events. I think that would help a lot because when you're in the [summer bridge] program, you're working with each other, so you kind of have to trust each other when it comes to like poking a cell or something like that. Just like having that confidence in each other would help by doing some social events"
Increased exploration of campus resources (2)	"I think one of the things that could be beneficial for the student [is] to really, I guess show all of the resources they could use"
More assistance in joining new lab (2)	"I would say if you can help the students be in a lab. If it's part of the program to help the student be in the research lab at the end of the program, then that would be very helpful. Because for me, I had to talk to the professors and ask them if they would have open positions in their lab and it took me like 3 months, but if the [summer bridge] program would have helped me with that, I could have like gotten a paper published or something better in that lab."
Increased stipend (2)	"If the stipends were a little bit more then it would be great, because it was really hard to budget during the summer with our stipends."

campus resources, more opportunities for social activities within the cohort, and more direct assistance with finding and pursuing future laboratory and internship opportunities. Additional standalone suggestions (coded only once in the data set) included better emphasis of program objectives prior to the start of the program and staff evaluation of participant progress throughout the duration of the program. The participant who advocated for increased staff evaluation of students' progress argued that it would be a mechanism to increase performance and accountability:

> *Some [students] rose to the challenge and some [students] would just not. Nobody was checking up on them. Nobody was saying, "did you do this, did you do every step of the way." And so, I think that some [students] didn't get as much out of it as possible because they were able to slip under the radar with various readings or aspects of projects. Like, if somebody was good at one thing and they were on your team, the people who were weaker at that skill, if they didn't want to, they might not have talked or spoken up and that wouldn't have gotten noticed. So, I think it would be nice to have, I think this might be really difficult, but like more people who have either done the [summer bridge] program or who are leading it like, [program faculty] to check in with people more often I think would be really nice to check on progress and see how people are understanding topics would be nice.*

Discussion

The summer bridge program described here was aimed with the broad goal of increasing participation of and retaining diverse transfer students in the STEM pipeline. Research preparation is often discipline specific and students typically seek research experiences based on their field of study. However, while the program curriculum focused on research experiences in biological sciences and most participants were majoring in biological sciences upon entry (Table 1), we focus on the program primarily as a case study of a unique phenomenon in higher education: a STEM intervention program for transfer students. As interpreted through the community of practice framework, the summer bridge program was structured to input participating transfer students as newcomers on the periphery of the research community, enculturate them into research practice, and foster interest and pursuance of research and related career opportunities in STEM (Figure 1). We now situate our results within these goals to reflect on the outcomes and insights arising from the implementation of our case study.

RQ1: Unique program structure supported positive affective and professional outcomes in STEM

Because of the time-intensive nature of the summer bridge program, students could not enroll in other classes or programs concurrently. Therefore, the short-term gains measured in the participants' self-efficacy in research skills can be directly attributed to experiences in the program curriculum (Table 3). Many of the skills with low differences between the pre- and post- program measures had relatively high ratings in the pre-program measure, such as utilizing feedback to improve one's work, analyzing data, and presenting research in writing. These skills are not necessarily unique to an out-of-class research experience and could arguably be obtained from previous coursework, including in non-STEM curricula.

Several of the items that were not significantly improved still had moderate effect sizes (>0.50). Skills such as using equipment and carrying out laboratory techniques, generating research questions and hypotheses, and working collaboratively with others are research skills that students are often exposed to in laboratory coursework, especially in course-based undergraduate research experiences (Auchincloss et al., 2014; Bangera & Brownell, 2014; Corwin et al., 2015). In contrast, the areas of most significant growth with the largest effect sizes can be attributed to unique features of the summer bridge program curriculum. Notably, the participants were able to synthesize their research skills and knowledge about the scientific process into a final project that required them to generate a hypothesis and then design, execute, analyze, and present their data. Through this culminating final project, students benefited from implementing and practicing their training in modes of communicating research, oral presentations, and written proposals. The opportunity to participate in this experience increased self-efficacy because students engaged in a process that is commonly enacted by experts in the research community.

The areas of research self-efficacy with the lowest pre-program ratings (<3.50 out of 6) included carrying out research where no one knows the outcome, carrying out a research project entirely of student design, and writing research proposals (Additional file 1: Table A-2). These skills are the essence of being a scientist and central to innovation and growth within the research community of practice. These large gains in self-efficacy indicate that the summer bridge program supported the inbound trajectory of these students toward the center of the community of practice by providing them with an opportunity to engage in the practices and tools that anchored them into the authentic culture of the scientific community.

In particular, the modules that were led by different faculty were intended to provide participants with breadth in skills that are applicable across many scientific domains, which students could then leverage in future research. Through the diverse modules, participants were enculturated into the community of practice by beginning with low-stakes activities through mutual engagement and support of faculty members. This legitimate peripheral participation allowed the participants to build the requisite foundational skill sets needed to continue to more complex tasks, and they became comfortable enough to experiment in a final project that was a low-stakes introduction to the critical thinking skills and innovation of experts. The opportunity to engage in a culminating research experience that was central and authentic to the practices of experts increased students' self-efficacy over the course of the summer program, allowing them to gain confidence in their skills as more established members within the research community of practice.

In the final project, students were granted autonomy to design their own hypothesis and experiment. This is a structural element that may prove advantageous over typical mentored research experiences where the mentor generates the hypothesis and decides which experiment is appropriate (Crisp et al., 2017; Fechheimer et al., 2011; Linn et al., 2015). Through the final project, students were given the agency to demonstrate their knowledge and understanding of the scientific process while still having the opportunity to consult with their mentor for guidance and support as they began to exercise their autonomy as a researcher. The increases in students' self-efficacy in research skills, including carrying out a project entirely of student design, lead us to speculate that the cognitive apprenticeship model was instrumental for balancing guided enculturation with emerging agency. However, future evaluation-based work will need to directly measure the extent to which participants see themselves as more centralized members of the research community by the end of the program to further assess the efficacy of this model.

Finally, effect sizes were quite large for participants' reported increases in feeling informed about navigational processes related to scientific career pathways, especially knowledge of what graduate school is like, career paths of science faculty, and what it is like to be a science researcher (Additional file 1: Table A-4). As part of each two-week module, students had the opportunity to be mentored by different faculty on a specialized topic and attend guest lectures from non-program faculty and graduate students. In addition to the concrete experiences in research skills and practices, integrating informal conversations about occupational advancement in the STEM field further grounded and oriented the participants toward a more holistic understanding of the cultural enterprise that is embedded within the research community. These advanced peers and mentors were able to articulate their unique trajectories into their career, providing the participants with a range of perspectives on what different pathways toward a scientific career could look like. These increases further demonstrate that the participants felt in closer proximity to the trajectories of more expert members within the community of practice, allowing them to feel more informed about how to carve their own pathways as they navigated new opportunities after the summer.

Outcomes with no differences in pre- and post- program measures

Participants reported a nearly identical sense of motivation for seeking help from others when struggling with concepts or material in the pre- and post- program measure, indicating that they did not improve in their comfort seeking assistance from faculty or students when they were struggling with concepts or material. These items were originally developed to be used in a traditional classroom setting, so the ratings may not directly reflect their comfort to seek out and master new skills and knowledge areas in a research setting. Duplicating the item structure in the context of seeking help in a laboratory setting may be needed to identify the program's influence on this dimension of the participants' development. Moreover, this post-program rating was collected after the program, but before the students took their first courses at the university. These survey items may need to be implemented as a longer-term evaluation measure to identify whether the program affected their ability to seek assistance from others as an academic and professional skill. We speculate the program may have benefitted the students long-term in this regard because many students described feeling more connected to faculty and researchers on campus because of the program (as investigated through RQ2).

Students' motivation for pursuing a scientific career was near the maximum in both the pre- and post- program measures, so there was likely a ceiling effect. It is no surprise that students applying to a science research training program had strong interest in a science career upon entry. Given that their motivation continued to be high at the end of the program, this metric further shows that the program environment maintained this initial interest. A more comprehensive science identity framework that includes interest and motivation as dimensions will be needed to further investigate how their interest may have affected their inbound trajectories into the research community of practice over time (Hazari et al., 2013; Hosbein & Barbera, 2020).

Participants' inbound trajectories in the community of practice were maintained following the program

It is possible for students to be repositioned as a peripheral member of the community of practice if their commitment lessens over time (Prefontaine et al., 2021). Although the program faculty encouraged participants to apply to laboratories and provided guidance on navigating the application process, participation in research following the program was not mandatory for participants. However, given that more than 90% of participants continued onto faculty laboratories following the summer and a majority continued onto career and graduate schools in STEM after graduating from the university, students maintained their inbound trajectories toward the center of the community of practice following the summer program. Therefore, the short-term, inbound trajectory during the summer program was maintained for nearly all participants as they neared the end of their undergraduate education and transitioned to the next stage of their professional careers. Although the program did not directly facilitate an application into new faculty laboratories, consistent inbound trajectories may be indirectly attributed to students' sense of belonging or connections facilitated by the program, especially for students who joined the laboratory of a program faculty member or guest speaker.

RQ2: The bridge component of the program supported students' academic and professional integration in the university

We primarily reflect on the program as promoting positive affective outcomes in relation to students becoming enculturated into the STEM research community of practice. However, the program's hybrid role in research training and as a bridge to support students through their transition to university necessitated the investigation of other dimensions of the students' experiences to gain a more holistic understanding of the programs' impact on the participants' development as scholars and lifelong learners. In contrast to traditional bridge programs, the research-intensive focus of our summer bridge program limited the time available to include structured activities about time management, academic success, etc. in addition to the activities that were part of the program curriculum. Regardless, many participants still articulated positive affective outcomes in their academic and professional development.

In reflection of the longer-term impact of the program at the end of their undergraduate careers, nearly all participants had perceived that they had obtained transferable academic knowledge or skills (Table 4). Like the scientific research skills that students had developed through the modules and project work, the academic skills that students obtained broadly applied across many STEM disciplines. The rigorous research experience organically provided students with foundational technical and non-technical skills needed to engage in higher order forms of thinking in advanced STEM coursework, thereby supporting their enculturation into the broader practices of STEM both inclusive of and outside a traditional research or laboratory setting. Therefore, most participants perceived that the program structure adequately prepared them for the rigors of university academics even without traditional forms of academic support that are typically implemented in non-research focused summer bridge programs (Ashley et al., 2017; Cooper et al., 2018; Douglas & Attewell, 2014; Garcia & Paz, 2009; Gonzalez Quiroz & Garza, 2018; Kezar, 2000; Kitchen et al., 2018).

The most frequently stated benefit of the program was the mentorship and networking-- most participants perceived that they felt more connected with faculty and researchers on campus and more confident in their ability to interact with faculty and ask for guidance. A student's identity as a developing scientist is informed by interactions with faculty, who act as agents of the norms of the scientific community of practice within their institutions (Carlone & Johnson, 2007). Faculty also provide psychosocial support by offering students' encouragement in the face of failure and recounting their own struggles, which can be applicable to both training in the scientific process as they are enculturated into the research community and reflecting on how to persevere through general academic and social challenges (Aikens et al., 2016; Anderson et al., 1995; Crisp & Cruz, 2009; Thiry & Laursen, 2011). Based on this feedback from the participants, the program's efforts to expose students to different faculty mentors and researchers may have been pivotal for helping the students overcome these barriers and perceive faculty as a resource to help navigate their academic and professional trajectories.

In contrast to these perceived academic and professional benefits, only about half of the participants perceived a greater sense of social integration on campus after participating in the program. It was hypothesized that a sense of belonging within a community of students and researchers would beget validation and strengthened identity as a member of the scientific community of practice, which would then increase their interest in pursuing other opportunities in STEM (Corwin et al., 2015). However, though students perceived a strong sense of social support in the program community, many students did not perceive integration within the broader campus community. - Participants who felt that they benefited socially had articulated that their sense of social integration was derived from learning how to interact with other students.

Although the participants had considerable academic success based on their post-graduation career outcomes, academic and social integration are often construed as overlapping spheres that promote positive academic outcomes (Deil-Amen, 2011). Therefore, more concerted efforts to improve social integration outside of the program could further help students develop relationships that enhance academic motivation, self-efficacy, and sense of membership within the larger campus community. Explicit efforts to require semi-regular participation in networking opportunities with other campus organizations and academic enrichment programs could potentially strengthen the impact on this dimension of the students' university experiences. This additional support network can be a fundamental component for access to new opportunities and psychosocial support that eases potential academic barriers and challenges.

Limitations

There are some limitations that should be accounted for when interpreting these findings. First, although we documented significant increases in self-efficacy and career knowledge and a range of academic and professional benefits following the participants' completion of the program, we regrettably had no comparison groups. Because the application process for the program sought to identify the most qualified candidates, a randomized controlled trial was not feasible. Future studies of students in other undergraduate summer research programs could be used as comparison groups to understand how the program structure may uniquely support student outcomes within this institutional context (e.g., Maton et al., 2016). These comparison groups could provide insights into how the hybrid bridge and research training program may uniquely benefit the participants' advancement in research skills and engagement in long-term opportunities in STEM research.

Second, we acknowledge the unique qualities of our participant sample, and we therefore do not claim broad generalizability in our findings. It is possible that a broader sample of students would have different outcomes during and following the program based on their prior academic preparation and experiences. However, the case study of summer bridge program could inform future design-based research to adapt further implementations in different institutional contexts with other populations of students.

Conclusion

In this study, we report a case study of a novel summer bridge program to prepare incoming transfer students for undergraduate research experiences. Most program participants successfully engaged in research, developed self-efficacy and knowledge about the research process, and continued into graduate school and careers in STEM (RQ1). Participants also articulated a range of benefits from participating, particularly in their academic and professional development (RQ2). Overall, most of the participating students valued the program experience based on the formative feedback provided at the end of their undergraduate education. These insights from our case study can inform the design and implementation of future iterations, particularly with the drawbacks and challenges articulated by our participant sample.

Other directions for future research

Although design-based research that focuses on the implementation and evaluation of our program model is a primary area of future effort, other avenues of research on student experiences could be considered in parallel. First, undergraduate researchers experience a variety of mentoring structures in their research experiences (Dolan & Johnson, 2009; Joshi et al., 2019). A missing piece in our case study was a direct triangulation of the mentorship relationship between students and the teaching assistant or faculty mentors in the program, as well as the new mentorship relationships that students built in their new laboratories after the program. Mentorship has been shown to influence student identities in science (Carlone & Johnson, 2007; Chemers et al., 2011), and the types of support that undergraduate trainees receive from faculty and postgraduates have depended on different mentoring structures (Ceyhan & Tillotson, 2020). A longitudinal investigation of the different mentorship structures that participants experience during and after their summer research experience can be informative for understanding how different stakeholders beyond the program can affect student trajectories toward professional pathways in science. With this information, the program faculty can support students' navigation of the mentor-mentee relationship and potentially build collaborations with the students' new labs to ensure that all students continue to grow in the technical and interpersonal skill sets needed to succeed in graduate studies and career pathways in science.

Second, a salient aspect of the community of practice framework is identity development. Moving toward central participation in a community through more advanced and complex tasks is central to developing an identity as a more expert practitioner (Lave & Wenger, 1991). However, our data did not provide insight into the identity trajectories of participants in the research community. Our study considers the roles that students take within the research community as they are enculturated into the practice, but it is also worthwhile to directly examine how individuals' identities are shaped by the community. Students' increased confidence in their skill sets and feeling informed about what it means to be a scientist indirectly allude to the competence and performance dimensions of their science identities (Carlone & Johnson, 2007; Hazari et al., 2013). Future quantitative metrics that directly measure the participants' sense of competence, recognition by important others, and interest (e.g., Hosbein & Barbera, 2020) in the scientific community, as well as interviews that focus on the long-term critical experiences that affect these dimensions of their science identities, would provide more comprehensive insights into how different academic and research experiences affect the inbound trajectories of the participants over time.

Finally, transfer students are diverse populations with unique life experiences and personal circumstances along their trajectories from community college to university (Jackson & Seiler, 2013). Applying frameworks that investigate the capital that these students draw upon and how their unique identities have affected their educational experiences will improve our understanding of how to support transfer students from diverse backgrounds in curricular STEM experiences (e.g. Archer et al., 2015; Yosso, 2005). It is important to understand how multiple systems of oppression intertwine to influence transfer students' experiences, systematic inequalities, and access to opportunities, which can, in turn, affect their sense of rightful presence in the research community (Calabrese Barton & Tan, 2019; Calabrese Barton & Tan, 2020). The diverse life experiences and backgrounds of students have the potential to enrich their learning experiences, so understanding how to provide spaces for transfer students to capitalize on their cultural wealth could potentially mediate positive outcomes for these students along their STEM educational trajectories. Insights from these studies would inform the development of inclusive programs and broader institutional practices that cultivate a sense of legitimized membership in the research community as we seek to broaden access and support the inbound trajectories of diverse transfer students into the STEM research community of practice.

Supplementary Information

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Additional file 1: Appendix 1. Sample Summer Bridge Program Schedule. **Appendix 2.** Pre- and post-program survey. **Appendix 3.** Data Tables. **Appendix 4.** Interview Protocol.

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Authors' contributions

ALZ conducted the post-program interviews, performed qualitative and quantitative data analyses, and wrote all sections of the manuscript. ALJ created the figures and contributed to all sections of the manuscript. ERM secured funding for and directed the summer-program, created and led one of the modules, and contributed to the introduction and methods sections of the manuscript. BLB created and implemented one of the modules during the summer-program and contributed to the introduction of the manuscript. TG created and led one of the modules during the summer-program, contributed to the discussion section of the manuscript, and provided edits to all sections of the manuscript. DA led the integration of summer-program participants with other research programs and campus resources. SML contributed to the study conception and design, qualitative and quantitative data collection and analyses, and edits to all sections of the manuscript. All authors read and approved of the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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