STEM Persistence Among Women, Non-Binary, and Students of Color: A Longitudinal Study of the Impact of a Residential Science-Oriented Summer Bridge Program

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Abstract

The United States faces challenges in retaining students of color (SoC), women, and nonbinary individuals in Science, Technology, Engineering, and Math (STEM). This study explores the impact of a residential bridge program on STEM persistence for these groups. Participants, who were all women or nonbinary individuals and were 56% SoC and 30% first-generation, consistently outperformed their peers who did not participate in the program. Overall, 82% of scholars graduated in four years (compared to a 59% college average), with 74% earning STEM degrees. Of particular significance, 81% of SoC graduated with a STEM degree and the first-generation SoC median graduation rate was 100%. Faculty mentorship played a pivotal role in students' success, highlighting the importance of a committed and engaged team. This, together with a focus on building a sense of belonging through cohort interactions, PAs, and community engagement proved instrumental in supporting student retention. For an effective STEM summer bridge program, we recommend fostering faculty mentorship and creating sustainable program formats. As balancing intensive learning and support mechanisms are vital for ensuring long-term student success and persistence in STEM. This study supports the transformative potential of a well-structured summer bridge program in enhancing the representation and success of historically marginalized individuals in STEM.

Keywords: Students of color, women, nonbinary, STEM, summer bridge, graduation, persistence

Introduction

In the United States, Science Technology Engineering, and Math (STEM) education and workforce are impacted by challenges in retaining students of color (SoC), women, and nonbinary people, who tend to switch from STEM to non-STEM majors at higher rates than white men. SoC, particularly those who identify as African American/Black, Latinx/Hispanic, American Indian or Alaskan Natives, or from two or more races, remain under-represented (National Center for Science and Engineering Statistics (NCSES), 2023). While high school GPA and performance in first-year courses are predictive of retention in STEM, even SoC and women who have high grades are more likely to drop these majors resulting in the well-documented "leaky pipeline" (Liu et al., 2019).

Students entering college with STEM majors have similar goals regardless of gender or ethnicity. For example, 39% of all students enter college intending to pursue a STEM major compared to 36% of Black students and 42% of Latinx students. Of all students entering college, 31% receive a bachelor's degree in a STEM field. In comparison, 9% of bachelor's degrees awarded to Black students and 16% of bachelor's degrees awarded to Latinx students are in STEM fields (National Science Board (NSB, 2022). Rates are lower in the physical sciences, where 18% of Black and 19% of Latinx students enter planning to major in a physical science field, but only 7% and 8%, respectively, of graduating students are awarded bachelor degrees in those fields (Chang et al., 2014).

Summer bridge programs are short-term initiatives strategically designed to help students navigate the academic and cultural transition from high school to college. Conducted before the start of the fall semester, these programs deliver essential skills and support structures, often addressing both the academic and non-academic aspects of the student experience. Several studies have investigated the impact of summer bridge programs on student preparedness and first-semester STEM GPAs. While some research findings correlate positively with the benefits of these programs (Fletcher et al., 2001; Garcia, 1991; Gilmer, 2007; Hicks, 2005), contrasting findings have demonstrated no statistically significant effect (Stewart, 2006; York & Tross, 1994). One limitation of these studies is that they are short-term, only following one or two cohorts for a few years after the summer bridge program. In 2007, Mills College, a historically women's college, designed a residential summer bridge program. The Hellman Summer (Science and Math) Program (HSSM) focused on STEM preparation to attract and retain STEM students. Here we present an in-depth, over a decade-long, examination of our summer bridge program. Our analysis highlights the effects of programmatic adjustments on student engagement, persistence in STEM disciplines, and graduation rates.

Impact and History of the Hellman Summer (Science and Math) Program

HSSM was designed to increase the self-efficacy, retention, and persistence to graduation of women SoC following research on the impact of summer bridge programs (Kuh & Schneider, 2008; Santiago, 2008; Strayhorn, 2011; Suzuki, 2009). From 2007-2021, 185 HSSM participants entered Mills College. Of these, 56% were SoC, 10% self-identified as African American or Black, 17% as Asian American, Asian or Pacific Islander, 14% as Latinx or Hispanic, 2% as Native American or Native Alaskan, and 14% as two or more races (Figure 1). In addition, 30% were first-generation students. HSSM students consistently cited their participation in this program as one of the most meaningful, useful, and memorable aspects of their college experience (Table 1).

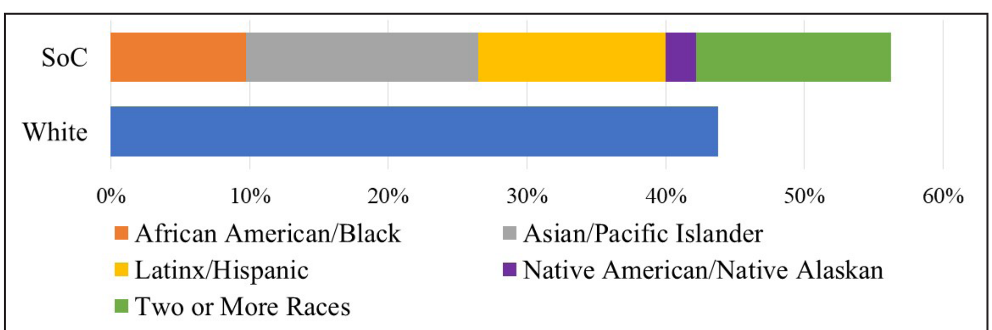

Figure 1: Student Demographics of Hellman Summer (Science and Math) Program Participants. Note: SoC = Students of Color

"I came to Mills in 2010 a 17-year-old kid with big ambitions and no idea how to achieve them. I am a first-generation college graduate and to say I was not prepared for college would be an understatement. Hellman gave me the space I needed to step into college with the knowledge and skills I would use for the next 4 years." – Liz	"Hellman was a reaffirmation and a wake-up call at the same time! I had always loved Science, and known that it was going to be my career, and participating in Hellman only intensified that desire, but it also taught me that it would take everything I've got to get there." - Heraa
"Not only did it teach me the fundamentals that every good biologist or chemist should know, it encouraged me to pursue a career in science and nurtured my scientific curiosity." – Jillian	"Hellman taught me to be more independent as a student and go out and seek help if I didn't understand the lecture or homework." – Gaby
"I developed lifelong friendships through Hellman, I learned about important Biology and Chemistry concepts, but most importantly I made an identity for myself." – Nicole	"It .. helped me to realize that I wanted to become a chemistry major because it's the first place I really saw what chemistry entailed." - Adira
"I became better prepared for my science classes in the fall, I gained more confidence in my intellectual abilities, and I feel that I became a stronger, smarter, and more mature person in general." - Andrea	"I am almost certain that I would have felt unable to major in a science if it weren't for Hellman. The first two semesters of college were still a shock, I can't imagine how I ever would have succeeded if I hadn't had Hellman to give me the extra push." – Ione

Table 1: Examples of Hellman Summer (Science and Math) Program Feedback Provided by Students.

For this study, we primarily focus on students who entered Mills College between 2007 and 2016 to enable discussion of graduation data. We consistently saw higher graduation rates for SoC (overall 81%), relative to all SoC at Mills College (overall 58%) who completed STEM degrees (Figure 2), except for the class that entered in 2010 when a change in financial aid policy increased transfer rates out of Mills College. In 2015 all entering HSSM students graduated from Mills College, but several opted for non-STEM majors. Also, in several years, all SoC who completed HSSM graduated with a STEM major, while for non-HSSM SoC who entered Mills College planning on a STEM major, 65% graduated with a STEM degree. Overall, HSSM scholars compared favorably (82%) to Mills College's four-year graduation rate (59%) with 74% of HSSM students completing STEM degrees.

We observed high GPAs for HSSM students, with no statistical difference between the GPAs of all HSSM students, HSSM SoC, or Mills College GPAs for all students regardless of major. It is well-documented that STEM GPAs tend to be lower than those of students in non-STEM fields (Whitcomb et al., 2021).

First-generation students in HSSM showed similar gains. At Mills College, the overall graduation rate for first-generation students majoring in STEM was under 40%, while the graduation rate for first-generation students who participated in HSSM was 50-100%, reaching 100% for five of the ten years of this study. Indeed, for first-generation SoC, the median graduation rate for HSSM students was 100%.

The success of our program was also demonstrated in the professional career paths of our alumni. Currently, our database tracks 55% of our program participants (101 former students), 84% of which have embarked on careers in STEM, or who are actively pursuing advanced STEM degrees. Notably, 36% of these professionals were

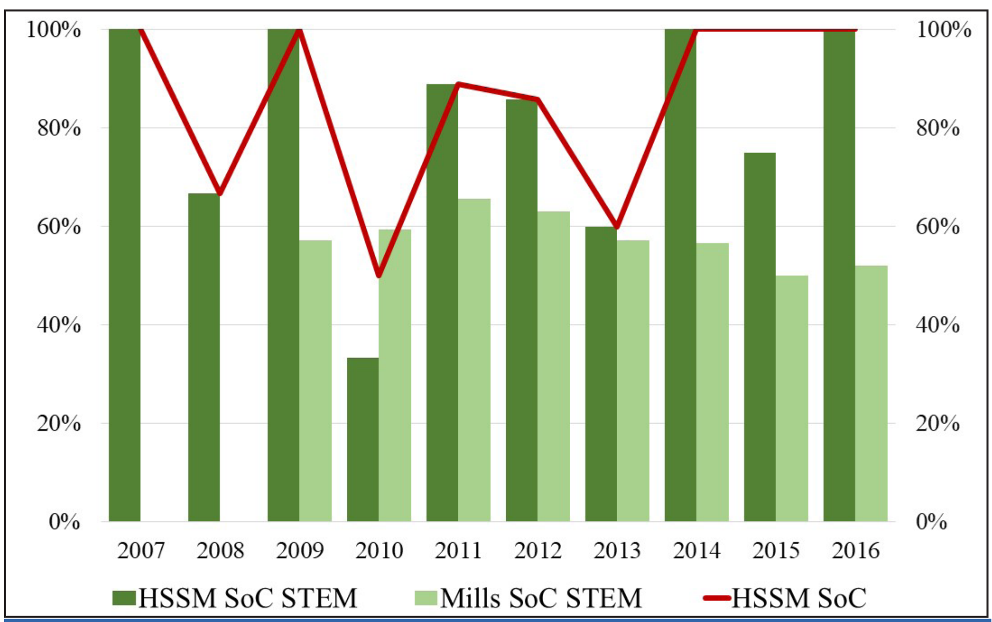

Figure 2: Graduation Rates of Hellman Summer (Science and Math) Program (HSSM) Students of Color (SoC) STEM Graduates Compared to Mills College Overall SoC STEM Graduates. Mills College SoC STEM graduation rates include HSSM SoC STEM data. Data is based on the year students entered Mills College, not the year they graduated. Before 2009 Mills College did not separate student demographics from degrees awarded.

first-generation students, and 57% are individuals from diverse backgrounds. These results confirm our commitment to an inclusive undergraduate environment and demonstrate the real-world impact of our program.

Initial Program Design

When HSSM began in 2007 it was a four-week program. The students, together with their invited families and friends, began with a day of orientation. This blended social activities and informative meetings to establish expectations and set a foundation for success. Clarity about the course schedule, the work expected, and the program events, was critical at this juncture. During this orientation, we emphasized the importance of seeking academic and socioemotional support proactively and managing time effectively. By inspiring our students to dedicate time to studying and completing homework, we fostered their academic self-confidence, thus facilitating the development of effective time management and organizational skills. We also discussed the significance of connecting with both faculty and peers, highlighting how collaborative learning could cultivate a sense of belonging and community.

Classes began with a workshop on digital tools, and we introduced our Learning Management System, class registration, and degree tracking programs. From 2017 we began enrolling our students in an iPad lending program. We found students either readily adopted and effectively utilized this new technology or encountered significant challenges. Students, particularly when engaging with iPads, struggled with distractions. There was also a learning curve, with many students not understanding how to effectively use iPads in an academic setting. The frustration often transitioned into reluctance which meant students frequently reverted to paper-based methods. Our workshops helped identify, assist, and encourage our less confident students. Technology was also intentionally integrated into the curriculum. We extensively used it in some classes, particularly where faculty were comfortable with the technology, while in others we chose different methods as a strategic approach to enhance the academic preparedness of our students. We did observe that during the academic year, students preferentially used the technology tools they had learned during the summer.

Our students were primarily placed into Calculus I and General Chemistry I in their first semester, as they were more successful if they completed chemistry before beginning General Biology I. However, this foundational sequence was frustrating to our biology majors, who represented a substantial number of HSSM students. Although many bridge programs only focus on first-year courses, we designed our program around topics in both chemistry and biology. These two foundational courses, and the skills embedded in them, played an important role in student retention and persistence to graduation.

Initially, students were invited to the program based on their interest in STEM and a math SAT score of 550-650 (or equivalent). The lower end of this range was selected because it reflected the score of students who were historically successful at Mills College as STEM majors. Later, we questioned whether the program could support students with lower scores. However, when invited, these students experienced higher levels of anxiety which were cited as reasons for withdrawing from the program and the institution. In 2016, we added a mathematics class to the curriculum. Additionally, Mills College moved to test-optional status. Our math unit emphasized effective strategies for word problems, unit analysis, and fundamental concepts in algebra and trigonometry. In 2016 and in subsequent years we still had students who disclosed their test scores ($n=26$), and those that did not ($n=18$). All reported SAT scores were (with two exceptions) over 550. Students eligible for our National Science Foundation (NSF) Scholarships in STEM (S-STEM, #1565160) awards were asked to provide their SAT scores in 2016, though not in subsequent cohorts. Some students, which we had not seen in previous years, faced challenges, leading the faculty member to instruct two cohorts within the same classroom. In addition, many of our students started placing into Pre-Calculus. Thus, to support our students, we added an introductory math concept class. Students were sorted based on our math placement test, which correlated to Pre-Calculus or Calculus I classes. All students who did not report scores, except for two international students, tested into the introductory class and later chose to enroll in Pre-Calculus. From 2016-2019, 65% of students who reported SAT scores graduated, compared to 61% of those who did not report, indicating the support strategies were effective.

Our unit on environmental chemistry helped students connect concepts between balancing chemical equations, stoichiometry, and unit analysis, with applications in the real world like acid rain and climate change. The environmental emphasis served as a counterweight to the focus on healthcare careers for the subset of students who were not planning to go into medicine. Chemistry laboratory experiments supported key concepts, introduced essential techniques, and fieldwork.

Our forensic biology unit was selected because students were familiar with criminology through popular television shows. Students were introduced to biological molecules (DNA, RNA, etc.) and biological techniques used in forensic laboratories, topics that they would see again in General Biology I. In the biology laboratory, students were introduced to the scientific method and formed a hypothesis after visiting a staged 'crime scene'. Experiments introduced students to theoretical knowledge and key biological techniques.

When students establish a strong connection within an academic community, higher levels of motivation, academic accomplishment, and persistence are evident. Development of this sense of belonging varies among students, but current research suggests four areas are pivotal: identification with the university, cultural capital, social match, and social acceptance (Maghsoodi et al., 2023). To foster a sense of belonging to the college and develop cultural capital, several initiatives were implemented. Students were linked to resources through presentations, facility visits, or a combination of both. These included the library, sports and recreation, counseling, psychological services, disability, and health and wellness. We organized social events such as joint lunches, thereby creating opportunities for our students to engage in conversations with program alumni, senior students, and other faculty, particularly those they would encounter in their first-year courses. Additionally, exclusive events with key campus administrators, including the President, Provost, and Vice-President for Student Life, were arranged for our students. Finding acceptance across all levels of the college infrastructure and within the leadership of the college, in our belief, contributed significantly to their sense of acceptance within the community.

While student-student interactions are key for retention at all levels of the academic journey they can be challenging in smaller cohorts. From the beginning, we strategically designed cohort groups both within the residential spaces and classrooms providing students with additional opportunities to forge connections with their peers and establish a sense of belonging. Students formed friendships almost immediately and we changed the group format as many times as possible to encourage new interactions. For example, students had different lab partners in both chemistry and biology. We mixed up groups for study sessions, project work, and for extracurricular activities. In the fall semester, when students resided on campus (which was not required), we placed them within the same living-learning community for their first year. With 16 students, we found many groups of two to four students who formed close relationships with each other, which persisted into the academic year and in many cases were retained through graduation and beyond. Those students who lived off-campus, usually 1-2 students a year, were less likely to form these close friendships, but frequent check-ins from our faculty helped keep them connected to the program.

Student-student interactions were facilitated by our peer assistants (PAs). These students lived with HSSM participants during the program, hosting study sessions, leading interactive pre-lecture sessions, attending lectures and labs, and joining students on weekend outings. At all times PAs exemplified successful student behavior: asking questions, prompting feedback, recommending study strategies, and supporting student transitions into the fall. PA sessions were mandatory during HSSM. This allowed us to assess and improve student study skills, immediately address specific concepts they found difficult, and respond quickly to issues such as homesickness or managing workload.

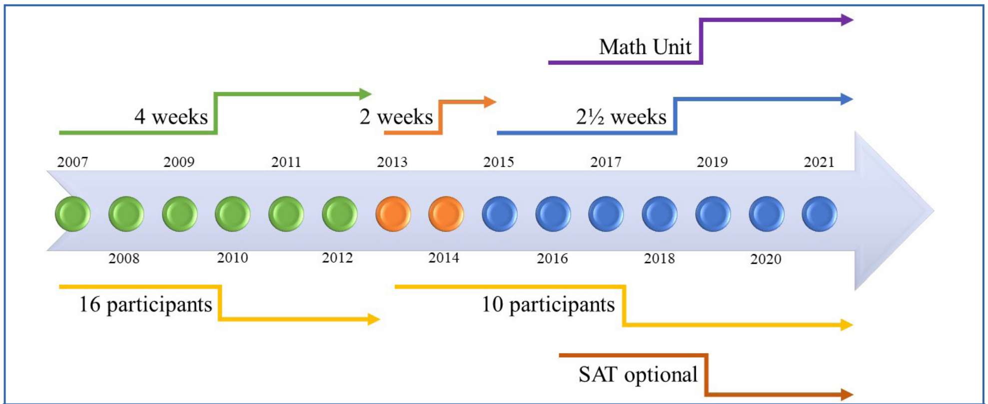

Figure 3. Timeline of Changes to the Hellman Summer (Science and Math) Program (2007-2021).

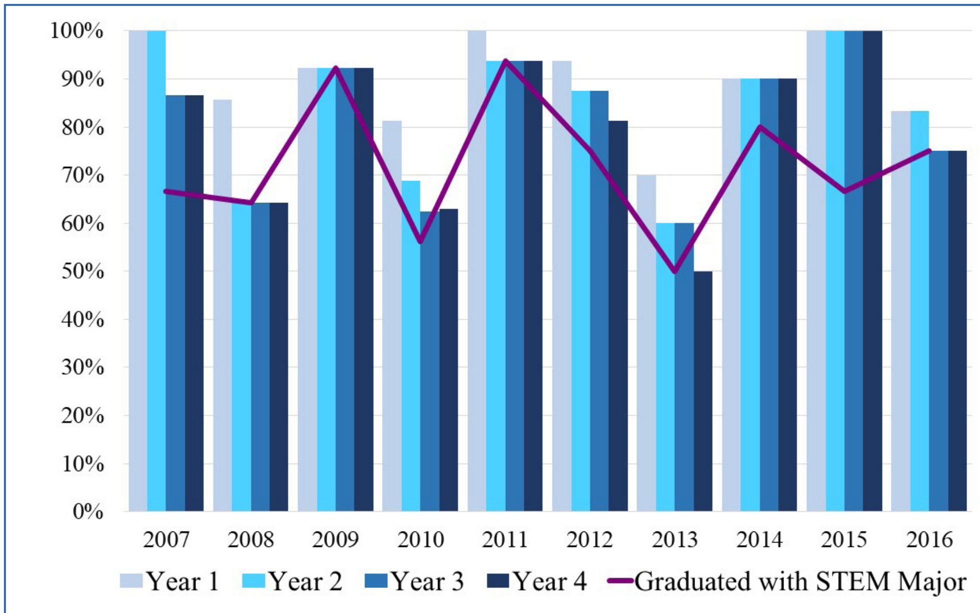

Figure 4. Hellman Summer (Science and Math) Program Persistence to Graduation by Entering-Year Cohort.

Scheduled programming events that focused on social and belonging goals were held on Saturdays to support cohort building. Led by the PAs, the events focused on student engagement with their community, orienting them to public transit, grocery stores, and shopping, ending with a trip to a local science museum. This programming also offered opportunities to connect HSSM students with alumni of the program and more senior students, who could offer different insights into success in STEM.

Changes to the Program

From 2007 to 2012, the format of HSSM did not change. Biology lectures and laboratory were taught by one instructor and the second instructor was both the chemistry lecture instructor and first-year advisor. There was some turnover in the chemistry laboratory instructor, with one instructor from 2007-2010 and another from 2011-2012, but both laboratory instructors participated in teaching the first-year chemistry sequence and worked with the chemistry lecture instructor during the academic year.

From 2013-2014, due to budgetary constraints, we reduced the HSSM program from a four-week to a two-week program and invited 10 students rather than 16 (Figure 3). During this time, we noticed several key challenges for our students. First, the shorter lectures were denser with material, which had been reduced but not halved. While students at the end of the program demonstrated similar growth in potential to those who attended the four-week program, students exhibited more stress. In addition, students did not have time to make the traditional mistakes we had seen in the four-week program, so poor quiz or lab report scores in the first week of the program led to demoralization, while in the longer format it motivated students to change and improve habits. We saw the impact of this discouraging experience on student persistence, where only 70% of HSSM students completed their first year at Mills College, as shown in Figure 4. That year, the lowest percentage (50%) of students graduated with a STEM major.

The second year of the two-week modality worked better once we significantly decreased the material covered in both chemistry and biology. For the 2014 cohort, 80% of students graduated with a STEM major, but their feedback still indicated that the two-week format was too intense, provided inadequate support, and left them less prepared for the fall. In 2015, we increased the time that students attended to two and a half weeks and added a fall semester component hosted by an HSSM faculty member. During the fall semester, we focused on a sense of belonging, extending invitations to external speakers to introduce students to various career pathways, and including topics on research and financial aid. We found the fall element in its entirety, together with a faculty member from the program as their advisor, to be a critical tool in retention.

In 2015, we were awarded an NSF S-STEM grant to provide additional infrastructure support mechanisms and scholarships for the students. This led to several changes in 2016 and 2017. We expanded the fields that were recruited into HSSM to include both math and computer science students and, as previously explained, added a formal mathematics lecture. Overall, students reported feeling more prepared for Calculus I but continued to struggle with engagement and balancing the workload of a third class. When we added a fourth class in computer science in 2017 it overloaded our students, and we received substantial negative feedback. We believe that two subjects with laboratories are optimal for student engagement, but three (three lectures, two laboratory) can be accommodated with thoughtful workload design.

In 2016, Mills College added a Community Engaged Learning Experience (CEL) core requirement, which we included in our fall semester programming. Although we would have preferred a more engaging and enriching career service-learning experience, various challenges emerged. The limited experiential experience of our students, the complexity of ensuring a consistent experience for all participants, and the program's proximity to the fall semester, presented significant obstacles. Our CEL integrated theoretical and practical STEM experiences into a tutoring opportunity with a local high school. This approach addressed our challenges but also provided students an opportunity to develop leadership skills through mentoring high school students. Overall, our CEL experience had varying levels of success. Transportation posed to be a significant hurdle, as our campus lacked a direct bus route. Additionally, many students lacked personal transportation. Another challenge stemmed from our students managing outside employment. In subsequent years, many students participated with our faculty in STEM research projects, served as teaching assistants, and found opportunities to participate in internships. We believe that careful conversations are necessary to support all majors, in all fields, in college curriculum initiatives.

To retain the NSF S-STEM scholarship, students needed to remain in a STEM field and maintain a 3.2 GPA. Each of our initial participants (six in 2016, eight in 2017) were placed into mentoring programs with faculty from the program, as in previous years, but with additional faculty mentoring based on their subject of interest. This additional mentoring did not seem to add to the program or retention. Students did not report finding them useful and indicated that the other support structures, such as their academic advisor, were sufficient. In 2017, we found students even less enthusiastic about these opportunities. In addition to the previous feedback, students reported struggling to find the time to meet with their mentor.

Our first S-STEM scholarship students graduated in 2019. Of the original six that entered, one left the program in 2015 due to a low GPA. However, she still graduated from Mills College with a STEM degree in four years. The remaining five students graduated with an average 3.59 GPA. Our second cohort lost three students who transferred to other universities and colleges. Two returned to their home states and the third opted for a co-education school. The remaining five graduated with a 3.57 GPA average. Originally, we thought that offering scholarships to STEM students would enable them to focus on their studies and pursue research internships without the need to engage in non-STEM-related employment. However, students still self-reported non-STEM employment of up to 10 hours per week.

Conclusions and Recommendations

Our primary recommendation for those considering offering or improving a first-year summer bridge program is to carefully consider the faculty involved. Faculty must meet the student where they are, understand when a student is struggling, and reflect a high level of accountability. Faculty need to be in consistent contact with these students in the first year. They must support the transition to the second year and need to be very familiar with college first-year resources. This often unseen and unpaid labor must be acknowledged for program longevity. We recommend that these contributions should be included in reviews, tenure, and promotion.

The implementation of a large faculty roster with a rotation of personnel is advised. This approach could have two faculty members assigned to teach the same subject, but one would teach the summer bridge and the foundational class one year, changing to the second faculty member the following year. This would prevent faculty burnout and bring fresh perspectives, ultimately enhancing the learning experience for students. We had success in utilizing adjunct faculty but recommend those who have been at the institution for a long period and are committed to mentoring students through their undergraduate experience. Hiring faculty just for the program and fall can be helpful but students would need connections to long-term mentors to offset this. We suggest a course release for faculty engaged in this work and for those faculty to be full-time, long-term, members of the academic community. Close collaboration among program faculty is vital. This allows for timely interventions that positively impact student success, thereby facilitating student persistence. For example, during the program, we graded work on the same day and shared assessment scores. There were frequent conversations about which students were struggling, and ways in which to support them, and for those students who were not struggling, we discussed how to challenge them. We also maintained a close relationship with our PAs about how they were doing in the residence halls. Women scientists led our program, and 90% of the STEM faculty at Mills College were women. Our faculty shared a commitment to advancing women in STEM due partly to their own experiences. Whenever a student was struggling, we would take advantage of each other's office hours to discuss and optimize strategies to help students persist. These relationships enabled timely interventions for our students. However, in the absence of this dynamic environment, it becomes key to establish a teaching and learning community among STEM first-year faculty to enhance student retention.

The number of weeks can have a significant impact on the success of a summer program. Four weeks allowed us to build the strongest program that prepared our students for the fall semester. However, this places a significant burden both on faculty and students. For faculty, this translated into less engagement in other teaching and research. Meanwhile, students potentially lost four weeks that could have been allocated to other responsibilities, particularly those related to income generation. Very short programs, of two weeks or less, are not ideal as students do not have the time necessary to form the habits they need for success and persistence.

Lastly, frequent and robust assessments should guide programmatic changes. We actively sought input from students and faculty throughout the program that encompassed both quantitative and qualitative aspects. External reviewers were also helpful in confirming our observations and in articulating perspectives we had not considered. The feedback, along with information provided by students after the program, meant that we were constantly refining and improving the program. While effective assessment can pose challenges, such as bias, validity, and reliability, as well as using valuable resources, it ensures programs are responsive to evolving needs, making it a vital component of any successful program.

Overall, we believe well-designed STEM-focused summer bridge programs have a significant impact on student sense of belonging, which in turn leads to higher persistence in STEM. However, it is critical to design a sustainable program that empowers students and prepares them to confidently navigate the academic challenges of a STEM degree.

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