Empowering Low-Income Students for Success in Computer Science and Engineering: The S-STEM Project at the University of Louisville

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Abstract

This paper introduces the S-STEM project, an innovative initiative implemented by the Computer Science and Engineering Department at the University of Louisville. The project aims to improve the success of low-income and academically talented students. Through the development of evidence-based curricular and extra-curricular activities, students are empowered to thrive in the fields of computer science and engineering. Spanning five years, the project's first cohort of three junior students achieved a remarkable 100% retention and graduation rate. Preliminary evaluations conducted in the first two years indicate the project's effectiveness, with S-STEM students expressing a strong likelihood of pursuing their current major within computer science and engineering.

Keywords

Low-income students, Computer Science, S-STEM, Student retention

1 Introduction

With the increasing use of artificial intelligence (AI) and data analytics in almost all sectors of society, the demand for highly skilled professionals in computer science and engineering is soaring. While we have witnessed a growing enrollment in computer science, the computing workforce still suffers from signficant disparities in the participation of financially disadvantaged and underrepresented groups compared to the rest of the population [1]. It is imperative to close this gap and bring a diverse group of talents to the technology workforce.

For students from low-income backgrounds, their educational journeys can differ greatly from those of wealthier peers [2, 3]. In addition to the lack of academic preparation and social connections, low-income students tend to have more factors influencing their academic success. Kezar et al. [2] found that they work more hours and are less involved. They are also less likely to take a full-time course load, live in the residence halls, or enroll continuously each semester. Our institutional data at the Speed School of Engineering of the University of Louisville (UofL) also indicate that low-income students have substantially lower retention rates and graduation rates compared to the overall engineering student population at UofL. Thus, offering scholarships and developing effective student support programs are essential for closing the gaps.

To address these issues, we applied for and successfully received an S-STEM grant from the National Science Foundation to support low-income academically talented students in computer science and engineering at the UofL. This grant aims to support 10 freshmen (each for up to 4

years) and 10 junior students (each for up to 2 years) who are Pell-eligible and high-achieving in pursuing bachelor's degree in computer science and engineering. Additionally, evidence-based educational activities will be developed to improve the retention, graduation, and employability of these low-income academically talented students. Some of the curriculum-wide changes and enhancement are expected to benefit all undergraduate students in our Computer Science and Engineering (CSE) programs.

2 Program Overview

While providing financial support is important to enable low-income students to secure time for studying, it is also beneficial to develop effective curricular and co-curricular activities to empower them for success. This project has developed a number of evidence-based program activities. This paper will overview the following project activities that aim at improving students' retention and success.

Better Preparing Students for Co-ops and Employment: The engineering undergraduate education at UofL includes a sequence of three semester-long on-the-job training experience through a mandatory cooperative education program. CSE students typically take their co-ops in the spring of Year 2, the fall of Year 3, and the summer of Year 4, with one semester of academic study in between. In the current BS CSE curriculum, students take the database course and software engineering course in their final year. However, discussions with employers (mostly local technical, healthcare and manufacturing companies in Louisville) and co-op students have revealed the importance of equipping students with basic knowledge of database and software engineering before they begin their co-ops. Therefore, the CSE department is developing two new courses: CSE 335: Introduction to Database and CSE 350: Introduction to Software Engineering and Application Development, which will be taught by CSE faculty before the first and second co-ops, respectively. The low-income, academically talented students in this program will have the opportunity to take those courses to better prepare for their co-ops. By practicing the database and software engineering skills in solving real-life problems in the industrial setting, we also expect students to deepen their understanding and better motivate and prepare themselves for more advanced studies in these topics after they return for academic studies following their co-ops.

Cohort Meetings and Networking to Build a Sense of Community: Low-income students enter college at a disadvantage and continue to suffer exclusion in various ways due to their economic background [4]. For example, some students may feel isolated and believe that they do not fit in with their classmates. To help build a sense of community and boost self-confidence, regular cohort meetings have been held among participants in this program. This provides a networking opportunity for all participating students to share their experiences with their peers and foster the creation of a learning community as an effective method to improve learning, retention, and persistence to graduation [5]. In some cohort meetings, we also invite guest speakers, such as industry professional, to discuss the expectations of employers in the profession of computer science and engineering. This provides an opportunity to expand their professional network or find industrial mentors.

Improving CSE Gateway Courses: A recurring problem for the retention of computer science and engineering students, especially first-year students, is the high failure rates in computer

programming [6]. For many of these students, it may be their first encounter with writing algorithms or programs. Programming is a process of translating a mental plan into terms compatible with the computer [8], which requires specific capabilities and skills, including the ability to grasp abstract coding concepts, problem-solving and decomposition skills, memorization of specific syntaxes, and the ability to use the semantics and structures of new non-natural languages [9]. We adopt the small group tutorial method [7], which has proven effective in improving students' programming learning and retention, allowing for more personal contact and creating a better sense of involvement for all. This is expected to benefit all students in those gateway courses, including the S-STEM program participants.

Undergraduate Research: Students in the S-STEM programs will have opportunities to conduct research with CSE faculty. The co-op program develops a research-track, where students can conduct full-time research for one semester, which can be counted towards meeting their co-op requirement. The project leadership team can also help connect students with other faculty with expertise in areas of students' interests. The CSE Department also hosts an research experience for undergraduate (REU) summer site in computing systems, which supports 10 undergraduate students to conduct research in a wide variety of topic areas in computing systems ranging from edge computing and energy-efficient computing to high-performance computer architecture and storage systems. S-STEM scholars can also apply for the REU program, and at least one S-STEM scholar has been selected to join the summer REU in computing systems.

Leveraging Existing Infrastructure: In addition to these project activities, the S-STEM project also leverage the existing student success programs at the Speed School of Engineering and the University of Louisville to empower S-STEM scholars. For example, UofL provides REACH (Resources for Academic Achievement), a centralized academic support unit to support academic success and retention of undergraduate students. REACH provides free and structured study sessions, regular and online tutoring, peer mentoring, coding camp, and seminars on student success topics. REACH also assists students in enhancing and improving their academic performance, transitioning to college life, and connecting to the university. Also, UofL's student success center offers a variety of programs, including Exploratory & Transition Advising, a First Year Experience program, Student Success Ambassadors, and Student Success Coordinators. In addition, the Speed School of Engineering provides the Academic and Leadership Center (ALC), which offers tutoring for upper-level engineering courses, a student leadership development program, a first-year networking program, and a resilience training program. All S-STEM scholars have been informed about these services and are encouraged to use them as needed.

3 Evaluations

This project includes both internal and external evaluation efforts. Dr. Jennifer Anderson who is the program director of the Teaching Innovation Learning Lab at the Delphi Center for Teaching and Learning of UofL, serves as a Co-PI and internal evaluator. The external evaluator is done by the external evaluator, MN Associates, Inc. (MNA) on an annual basis.

Figure 1 presents the demographics information for the cohort that we recruited in Year 1 of the program (i.e., AY 21-22). Due to the pandemic, it was hard to have in-person contacts with local high schools. However, we were able to reach out to prospective low-income students virtually and increase their awareness and information about the S-STEM program.

An S-STEM project website [9] linked directly to the Computer Science and Engineering (CSE) Department website at UofL was developed and has been fully functional since summer 2021. The project website provides details about the eligibility and application information, enabling students to submit their applications directly. The Principal Investigator (PI) has collaborated with the admission office and our academic or industry partners to promote the website and attract more low-income, academically talented applicants to the program. To ensure convenience for prospective students, the PI worked in collaboration with the admission office to integrate the S-STEM scholarship information into Slate, UofL's portal used for admission applications. The PI and Co-PI also presented the S-STEM program to rising junior students in the CSE Department, encouraging qualified students to apply.

With these concerted efforts, we successfully recruited a diverse group of seven low-income, high-achieving students, consisting of four freshmen and three juniors, for the first year of the project. As of the end of the spring 2023 semester, all three junior students have graduated, achieving a 100% retention and graduation rate for this particular cohort of students.

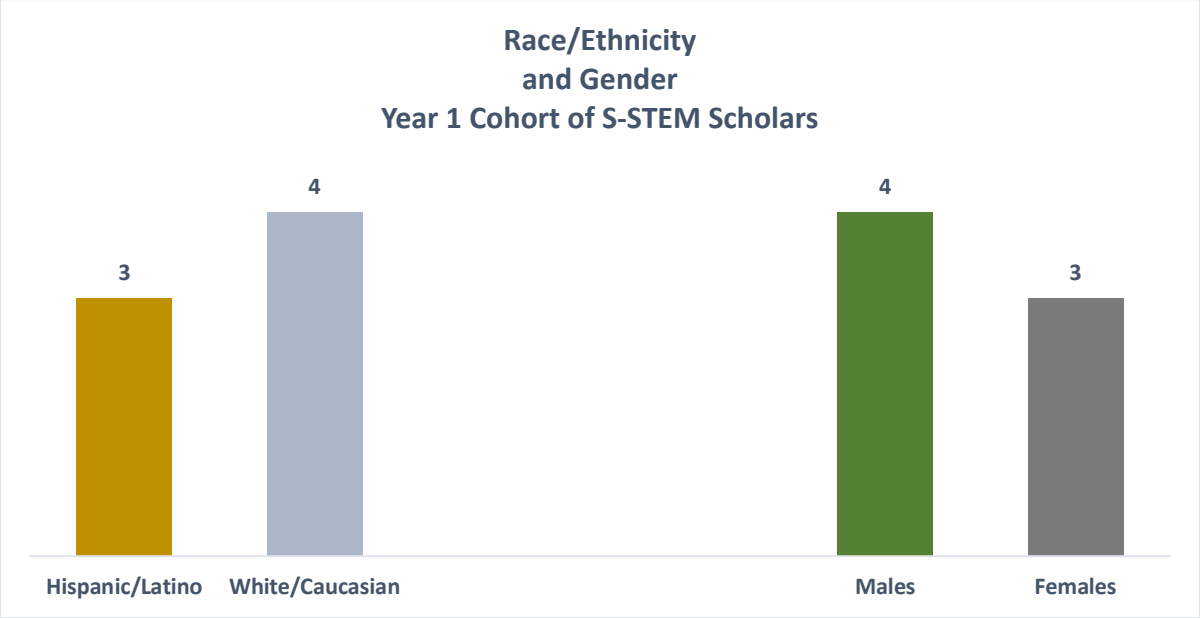

Figure 1. Demographics of S-STEM cohorts in Year 1 (AY 2021-2022).

An online survey was conducted to gather feedback on the team's year 1 planning and implementation efforts, as well as the ongoing support provided to the seven scholars. The survey included general perceptual questions aimed at assessing the satisfaction levels of participants. The results of the survey are summarized in Figure 2.

Upon analysis of the survey responses, it was evident that the overall satisfaction with the project planning and implementation was extremely high. The feedback received indicated that the efforts put into designing and executing the project were well-received and met or exceeded the expectations of the scholars. The participants expressed their appreciation for the thoroughness and effectiveness of the planning process, which enabled them to seamlessly navigate through the program.

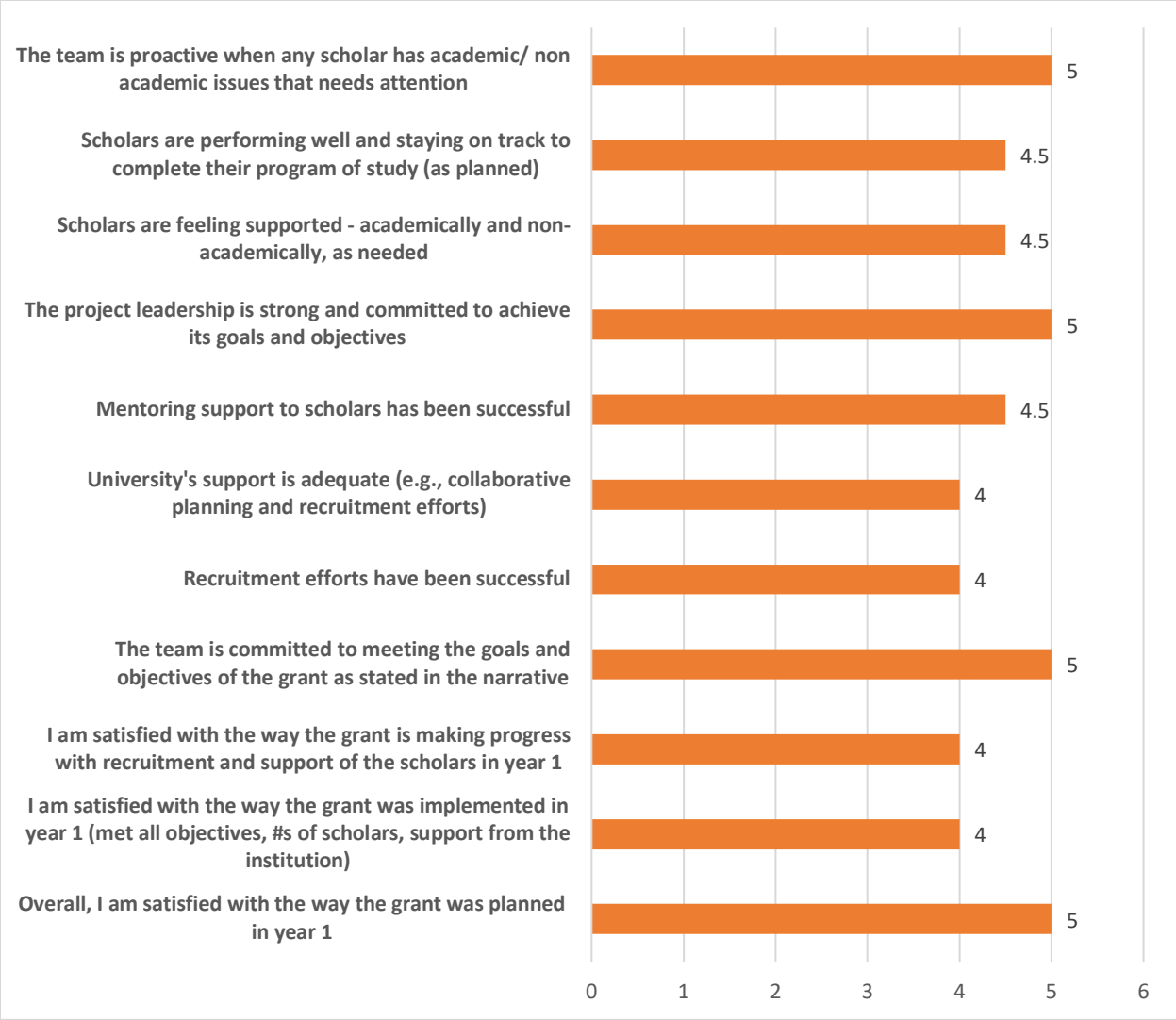

Figure 2. Extent to which the S-STEM project is functioning.

Another suevey was done in the end of Year 2, and the results are shown in Table 1 below.

Item/Activity	Mean score (max. of 5)
Overall, I am satisfied with the way the grant was planned and implemented in year 2	4.7
I am satisfied with the way the university provided support to our Scholars	4.3
Recruitment was successful in year 2	4.0

The team remains committed to meeting the goals and objectives as stated in the grant narrative	4.7
Mentoring support has been adequate	4.7
Scholars are feeling supported: academically and non-academically	**5**
Scholars are performing well and staying on track to complete their program as planned	**5**
My team is proactive when any scholar has academic or non-academic issues that need attention	**5**
Research work is being conducted as planned	4.7

Table 1. Extent to which the S-STEM project is functioning and services being provided.

The impact of program components was assessed using Likert-scale questions that asked students to indicate their level of agreement (ranging from 1= strongly disagree to 5= strongly agree) regarding the extent to which the components enhanced their academic performance, which is shown in Table 2. Data analyses were conducted to examine both pre/post differences and differences as students progressed through the program, aiming to evaluate whether the perceived value of program components varied based on student classification. Out of the ten students, seven provided responses for each survey, resulting in a response rate of 70%.

The key findings of the study are as follows:

• S-STEM scholars expressed a high likelihood of continuing to pursue their current major within computer science and engineering, indicating a positive impact of the program on their career aspirations.

• Although the differences in survey results across different semesters were not statistically significant due to the limited sample size (low n), students generally reported the highest level of satisfaction with their educational experiences in September 2022 compared to previous semesters.

• In certain categories, satisfaction levels slightly decreased from September 2021 to January 2022; however, these changes were not statistically significant. Further investigation could explore whether there is an adjustment period for students during and immediately after their first semester in the program.

• Overall, students expressed satisfaction with the S-STEM program, and their suggestions for improvement were limited.

In summary, the study revealed positive feedback from students regarding the impact of program components on their academic performance. While statistical significance was not observed due to the small sample size, students reported the highest satisfaction with their educational

experiences in September 2022. The findings highlight the overall satisfaction of students with the S-STEM program

	September 2021 *n*=7	January 2022 *n*=7	September 2022 *n*=7
For the question below, respondents answered on a 5-point scale where 1=very unlikely, 2=unlikely, 3=neither likely nor unlikely, 4=likely, 5=highly likely			
How likely is it that you will continue to pursue your current major after this semester?	4.86 (0.38)	4.71 (0.49)	**4.71** **(0.49)**
For the questions below, respondents answered on a 5-point scale where 1=strongly disagree, 2=disagree, 3=undecided, 4=agree, 5=strongly agree			
Overall, the teaching methods I have received in previous educational experiences were helpful and effective.	3.86 (0.38)	3.86 (0.38)	**4.57** **(0.53)**
My previous educational experiences provided me with a variety of learning materials and activities to promote my learning.	3.57 (0.79)	4 (0.58)	**4.43** **(0.79)**
On average, I enjoyed how my previous instructors taught.	4 0	3.57 (0.79)	**4.43** **(0.53)**
On average, the teaching materials used in my previous educational experiences were motivating and helped me to learn.	3.43 (0.79)	3.57 (0.79)	**4.29** **(0.76)**
The ways my previous instructors taught were suitable to the way I learn.	3.50 (0.84)	3.57 (0.53)	**4.57** **(0.53)**
I am confident that I mastered the content that my previous instructors presented to me.	3.57 (0.98)	3.71 (0.95)	**4** **(0.82)**
I am confident that my previous courses covered critical content necessary for the mastery of the course.	4.14 (0.38)	3.57 (0.79)	**4.14** **(0.69)**
I am confident that I developed the skills and obtained the required knowledge from high school and/or previous college to be successful at this university.	4 (0.82)	3.86 (1.07)	**4.14** **(1.07)**
My instructors used helpful resources to teach their courses.	3.57 (0.79)	3.86 (0.69)	**4.42** **(0.53)**
It is my responsibility as a student to learn what I need to know from my course.	4.14 (0.69)	3.57 (0.79)	**4.71** **(0.49)**
I know how to get help when I do not understand the concepts covered in a course.	4.14 (0.69)	3.86 (0.69)	**4.29** **(0.76)**
I know how to use activities in a course to learn critical aspects of course skills.	3.71 (0.76)	3.43 (0.53)	**4.29** **(0.95)**
It is the instructor's responsibility to tell me what I need to learn about a course activity or content during class time.	3.71 (0.49)	4 (0.58)	**4** **(0.82)**

Table 2. Survey of impact of program components.

4 Concluding Remarks

The S-STEM project at the University of Louisville's Computer Science and Engineering Department demonstrates the great potential of evidence-based interventions to to uplift the academic achievement and increase the retention and graduation rates of low-income and academically talented students. Through a five-year initiative, the project empowers students with the necessary tools, mentorship, and financial support, enabling them to pursue their studies and achieve their academic goals in computer science and engineering. Initial evaluation results highlight the project's effectiveness, with a 100% retention and graduation rate achieved by the first cohort of three junior students. Furthermore, early feedback from S-STEM participants demonstrates a strong inclination to continue pursuing their majors within the computer science and engineering disciplines.

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