Development and First-Year Outcomes of a NSF-Funded Summer Research Internship Program to Engage Community College Students in Engineering Research

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Abstract

Increasing the recruitment and retention of engineering students is essential to produce sufficient professional engineers for continued US economic growth and competitiveness in today's technology sectors. Undergraduate engineering research experience has been identified as an effective approach to increasing student engagement, academic performance, and retention rates. Community colleges play a significant role in today's US higher education; however, conducting basic research at community colleges is challenging due to limited resources and opportunities. With support from the National Science Foundation's Improving Undergraduate STEM Education: Hispanic-Serving Institutions (IUSE-HSI) Program, a collaborative summer research internship program between a public four-year degree institution and two local community colleges provided community college students with impactful engineering research opportunities and hands-on experiences. In summer 2022, the 8-week research internship program engaged nine community college students from diverse backgrounds to participate in four engineering research projects across several engineering disciplines. Each project team was supervised by at least a faculty advisor and a student peer mentor enrolled in the four-year university. The research project outcomes of the internship, as well as the external evaluation results, have shown that the summer research internship program delivered its objectives to have student interns gain valuable engineering research experience, strengthened their confidence in problem solving, and reinforced their interest in pursuing an engineering degree. Furthermore, the program improved the students' technical skillset, team collaboration, time management, and communication skills. The first-year development and implementation of the program, as well as its outcomes and lessons learned, will be presented in this paper.

Introduction

Based on information from the US Census Bureau and the National Science Foundation (NSF), the percentage of underrepresented minorities (URMs) in the US population has grown from around 30% to 40% over the past decade [1]. However, URMs still represent only about 14% of baccalaureate degrees conferred in engineering, and this percentage has remained relatively unchanged since 2010 [2]. To enhance the US engineering workforce, it is crucial to promote diversity and inclusion by encouraging and retaining students from URM groups in engineering majors. This will bring diverse skills, talent, backgrounds, and viewpoints to the technical workplace, which are essential for innovation, productivity, and economic growth [3].

Undergraduate research experience has been recognized as an effective approach for enhancing academic performance, retention and graduation rates, and motivation to pursue graduate studies among URM students [4]–[8]. Numerous studies have demonstrated the benefits of undergraduate research, such as the development of critical thinking and problem-solving skills, preparation for graduate school or a research career, and the enhancement of communication and teamwork skills [9]–[12]. While community colleges play a significant role in US higher education, with roughly one-third of undergraduate students enrolled in these institutions, research opportunities at community colleges can be limited due to resource constraints. To address this challenge, establishing partnerships between research universities and community colleges is essential to promote undergraduate research opportunities and encourage students to engage in research from the beginning of their college education.

San Francisco State University (SFSU) is a public four-year Hispanic-Serving Institution (HSI), an Asian-American and Native American Pacific Islander-Serving Institution (AANAPISI), and a Primarily Undergraduate Institution (PUI). The School of Engineering at SFSU has a highly diverse student body of 1,300 students, of which 44% are URMs and 16% are women students. About 40% of the enrolled engineering students are transfer students from community colleges. Although entering with high levels of interest in engineering, many of the URM students struggle to complete their degree due to various factors: inadequate academic preparation, insufficient awareness career options, lack of necessary financial, academic, social, and cultural support for success, and low levels of self-efficacy.

To address these barriers and build capacity for student success, SFSU has partnered with two local HSI community colleges, Skyline College and Cañada College. This collaboration involves developing and implementing several strategies through the *Strengthening Student Motivation and Resilience through Research and Advising (S-SMART)* project, which is funded by the National Science Foundation's HSI Improving Undergraduate STEM Education (IUSE) program. One of the strategies developed is the *S-SMART Summer Internship Program*, which offers community college students who have limited previous research experience meaningful opportunities to engage in engineering research with close mentorship from faculty and peer mentors, as well as gain hands-on teamwork experience. Research has shown that close mentorship and teamwork can enhance academic performance, increase retention and persistence to graduation, improve confidence and self-efficacy, and enhance career preparation, particularly among URM students [13]–[15]. The eight-week summer internship program aims to have ten to twelve community college students from diverse backgrounds in group research projects across several engineering disciplines within research labs at SFSU School of Engineering. This paper presents the first-year development, implementation, and outcomes of the program with plans for future program improvement.

First-Year Implementation of the S-SMART Summer Research Internship Program

In 2022, the S-SMART Summer Research Internship Program was piloted with a cohort of ten students participating in four research projects across three engineering disciplines - civil engineering, computer engineering, and mechanical engineering. Each project team was supervised by at least one faculty advisor and one SFSU student peer mentor.

Recruitment and Selection of Program Participants

The S-SMART interns were selected through an online application process. The application form, created on Qualtrics, asked for information including GPA, intended major, completed STEM courses, academic and career goals, research interests, relevant experiences and skills, and a recommendation letter from a STEM instructor. Applicants were also required to rank their preferred SFSU engineering research labs, which were listed in the application form with links to lab websites. A program advertising flyer was made to provide an overview of the program, application information, and program benefits, including a $4,000 stipend for each intern. In January 2022, the community college coordinators at Cañada College and Skyline College promoted the opportunity to their students and faculty. Additionally, SFSU faculty members presented their research and introduced their labs to community students through a virtual winter scholarship program, which was co-organized by Skyline College and SFSU in mid-January 2022.

By the March 15, 2022 deadline, a total of 44 completed applications were received for the S-SMART research internship program. SFSU faculty advisors reviewed the applications and selected participants based on the student's interested research areas, academic performance, and completion of relevant STEM courses and experiences. They communicated directly with top candidates for further interviews and selected 10 students to join four participating research labs, including the Complex Fluids Laboratory, Controls for Assistive and Rehabilitation Robotics Laboratory, Intelligent Computing and Embedded Systems Laboratory, and Intelligent Structural Hazard Mitigation Laboratory. However, one of the students had to withdraw from the internship in the second week of the program due to a personal emergency. Eventually, a cohort of nine student interns completed the internship. Table 1 provides an overview of the program participants' demographics, with 33.3% being female. The racial and ethnic distribution of the participants was as follows: 22% Asian, 22% Hispanic, 22% White, 11% Black, 11% American Indian or Alaska Native, and 11% multiracial. The program was successful in recruiting women and URM students.

Table 1. Demographics of the 2022 S-SMART Summer Research Internship Program participants

Demographics	**# of Students**	**(%)**
Gender		
Male	6	67%
Female	3	33%
Total	9	100%
Race/Ethnicity		
Asian	2	22%
Hispanic	2	22%
White	2	22%
Black	1	11%
American Indian or Alaska Native	1	11%
Multiracial	1	11%
Total	9	100%

Table 2 illustrates the breakdown of student majors in each of the research labs at SFSU that took part in the program. Of the program participants, eight were pursuing degrees in engineering, while one was majoring in Biochemistry. Each participating research lab hosted two or three students.

Table 2. Declared majors of the 2022 program participants for each SFSU research lab

	Matched SFSU Research Lab			
Major	**Complex Fluids Laboratory**	**Controls for Assistive and Rehabilitation Robotics Laboratory**	**Intelligent Computing and Embedded Systems Laboratory**	**Intelligent Structural Hazard Mitigation Laboratory**
Aerospace Engineering		1		
Biochemistry	1			1
Civil Engineering				
Computer Engineering			1	
Electrical Engineering			1	
Engineering	1			
Industrial Engineering				1
Mechanical Engineering		2		
Total	2	3	2	2

Program Activities

The eight-week internship program included a series of activities for all participants, including an opening day, a mid-program presentation day, and a closing day. The rest of the program focused on group activities for individual research projects. The opening day morning activities include breakfast and welcome remarks, introduction of team members, project overview presentations given by the faculty advisor of each group, a tour of the School of Engineering facilities and research labs, followed by a campus tour and then lunch. In the afternoon, the student interns completed a pre-program survey and a group Zoom interview with the external evaluator of the program. The progress and outcome of the research projects were evaluated through mid-program and final oral presentations, as well as a final written report. A mid-summer team building activities for after-hour social event was administered to build community between student mentor and mentees. The final presentations occurred on the closing day of the program, followed by exit-program surveys and interviews with the external evaluator.

Research Projects

The research topics and activities assigned to the program participants were determined by SFSU faculty advisor based on the students' level of preparation, existing research initiatives in the lab, and the availability of peer mentors in specific areas of interest.

Complex Fluids Laboratory: The goal of this project was to introduce community college student interns to the iterative nature of the mechanical design. The project focused on designing, prototyping, and ensuring the quality of hooks with a desired shape and style that could hold five pounds of weight. The hooks needed to fit and pass through the holes of a metal railing and hold lab coats. SolidWorks (Dassault Systèmes) was used to design the hooks, perform a finite element analysis, and predict stress, deformation, and safety factor distribution upon applying an external tensile load. An Ultimaker 2+ Connect Fused Deposition Modeling (FDM) 3D printer with Polylactic Acid (PLA) resin was used to prototype the hooks. A control hook was first prototyped using default 3D print parameter settings, and the ultimate strength of the hooks was then examined as a function of 3D print parameters such as infill type and density, print speed, and layer height. To assess dimensional tolerances, students used a NEIKO 01407A Electronic Digital Caliper to measure the diameter of the prototypes at several locations and compared it to nominal values specified in the design. The open-ended nature of the case study aimed to encourage students to come up with their own desired shape and style while meeting the design criteria.

Controls for Assistive and Rehabilitation Robotics Laboratory: The focus of this project was to design and build a soft robotic hand exoskeleton (i.e., exo-glove) using rapid prototyping manufacturing techniques. This new exo-glove provides an affordable, assistivehand exoskeleton to help stroke patients rehabilitate from hand impairment. The proposed exo-glove design used a lightweight, flexible finger design with a cable-driven, rackand pinion linear actuation system to provide the push-pull force and actuate finger motion. It incorporated a soft additive manufacturing technique, which enabled the fabrication of the exo-glove at a fraction of the cost of commercial exo-gloves Force-sensing resisotrs were attached to the exo-glove finger tips to measure finger force for user feedback when grasping objects. Subject tests were conducted to assess the exo-glove's performance specifications. The exo-glove demonstrated pinch grasping actuation with the thumb and index, producing a linear closing grasp speed of 1.2 in/s. By allowing for at-home therapeutic care, the lightweight, low-cost exo-glove through accessible manufacturing techniques has the promise to provide increased accessibility to underserved community patients.

Intelligent Computing and Embedded Systems Laboratory: This project aimed to create an intuitive and robust control interface for a robotic exo-glove capable of identifying the user's intended grasping movements. The interface incorporated three sensing inputs: surface electromyographic (EMG) signals, voice commands, and camera input. Two MyoWare Muscle Sensors (Advancer Technologies) measured forearm muscle activities to precisely trigger the exo-glove's grasping motion. An ESP32 microcontroller unit with integrated Wi-Fi and Bluetooth enabled the EMG sensing, processing, and control system. An Android device implemented a voice recognition module to select control profiles for the exo-glove, while a Jetson Nano developer kit running a deep learning-based computer vision module detected the object to be grasped and measured distance for more accurate control. The project provided hands-on experience in embedded system design, machine learning, human-machine interface design, and computer vision.

Intelligent Structural Hazard Mitigation Laboratory: This project is designed to validate the integrity of a wooden walk path in the laboratory and investigate the effects of several distinct floor surfaces in capturing walking patterns. The American population is aging. According to the most recent report from the Census Bureau, more than 20% of U.S. residents will be 65 and older in 2050. The increasing aging population calls for developing tools to connect healthcare professionals with older adults and perform smart at-home assessments in an automated fashion. Monitoring older adults’ activity routines automatically in their homes or dwelling could substantially and positively impact their health monitoring and reduce the need for healthcare professional interventions. As a unique identifier, human gait has demonstrated its ability to track health status changes in a controlled environment (e.g., a doctor's office). However, all prior gait studies have been performed in a controlled environment, not at the participant's home or dwelling. Determination of the relationship of these variables in a free-living environment will allow for an improved understanding of the link between the change in gait and health conditions. Furthermore, compared to the cross-sectional in-lab assessment, continuous monitoring will allow for an enhanced understanding of changes in gait from day to day that may alert the healthcare team to a change in functional and health status. Through a collaborative project funded by the National Institute of Health (NIH), the Intelligent Structural Hazard Mitigation Laboratory at SFSU is developing the fundamental knowledge needed to establish an always-on, non-intrusive, non-wearable sensing system for the automated estimation of at-home gait parameters using floor vibrations. In this project, the students investigated the integrity of a wooden walk path constructed the same way as in a typical house. In addition, they performed walking experiments on various floor surfaces (e.g., carpet, laminate wood, hardwood, and tiles) and tested their effects on capturing the walking signals. The project helped the team better understand the challenges of measuring walking signals in real-world applications.

External Evaluation Results of the 2022 S-SMART Summer Internship Program

The external evaluator of the S-SMART program conducted pre- and post-program surveys on all community college interns. Post-program surveys were also conducted on student peer mentors and faculty. The student intern survey measured the importance of knowledge, skills, and experiences gained from the internship, as well as perceptions of education, career, research, self-assessed proficiency, and internship experience. Figure 1 shows the average importance rating of knowledge, skills, and experiences students may gain from the internship; all the listed items were considered very to extremely important by the students. The most important item was gaining hands-on research experience, followed by working with others in an engineering lab, developing problem-solving, interpersonal and teamwork skills, and thinking like an engineer.

Figure 2 displays the results of the pre- and post-program surveys, which assessed student perceptions of education and career. After completing the internship, students exhibited increased confidence in their ability to transfer to a 4-year institution and complete a BS degree in engineering. They also had a greater understanding of the career opportunities available in engineering and a clearer career path. Students expressed agreement or strong agreement in feeling like part of a learning community. Most student interns could imagine themselves pursuing a master's degree in engineering, though only one strongly agreed with the idea of pursuing a Ph.D. in engineering, while the others either slightly agreed, slightly disagreed, or disagreed.

Figure 3 presents the results of pre- and post-program surveys measuring student perceptions of their self-assessed proficiency. Prior to the internship, students slightly agreed or agreed with eight out of the 13 assessed items, and agreed or strongly agreed with the remaining five items. Upon completing the program, students expressed agreement or strong agreement with all 13 items, with increased agreement across all items compared to pre-program results. The largest improvement was the ability to create effective engineering research posters (from 3.8 to 5.7), followed by the ability to use engineering software tools (from 4.3 to 5.8), write effective engineering reports and papers, give effective oral presentations (from 4.3 to 5.3), and interpret experimental results (from 4.3 to 5.3).

Figure 1. Students assessed the importance of knowledge, skills, and experiences. Survey Question: The following is a list of some of the knowledge, skills, and experiences you may have gained from your internship. Please indicate how important each of these is to you (1-Not Important, 5-Extremely Important).

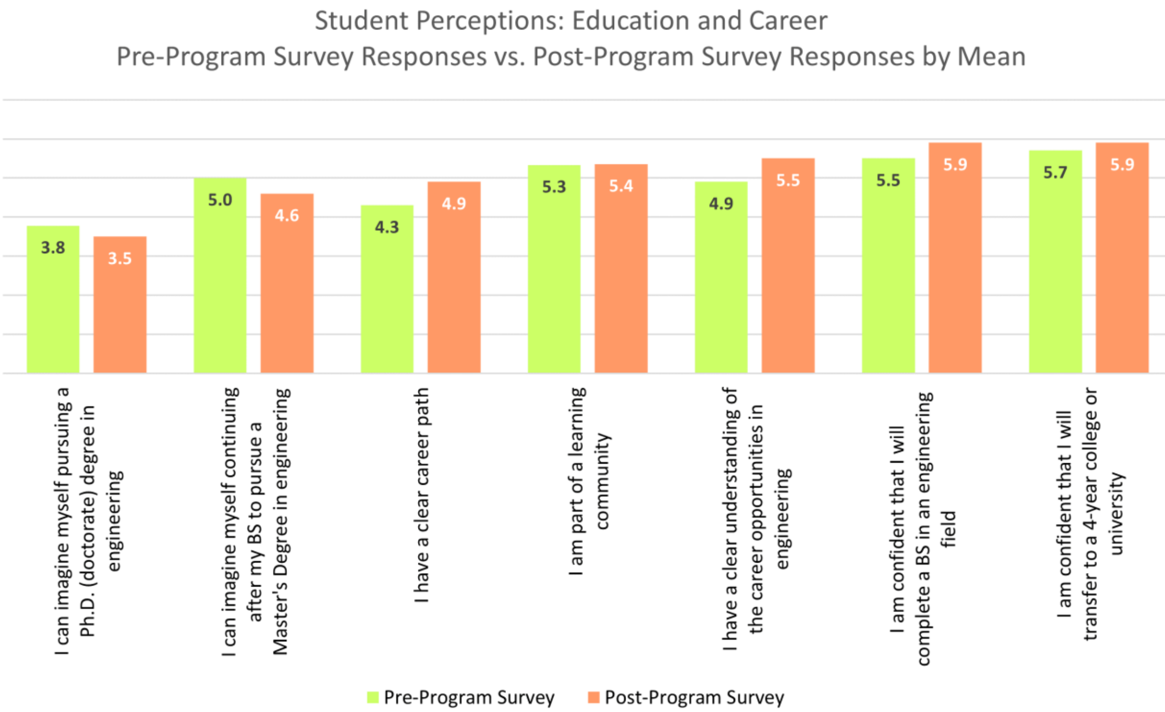

Figure 2. Results from the survey on student perceptions of education and career. Question: Please indicate your level of agreement with the following statements. (1-Strongly Disagree, 6-Strongly Agree)

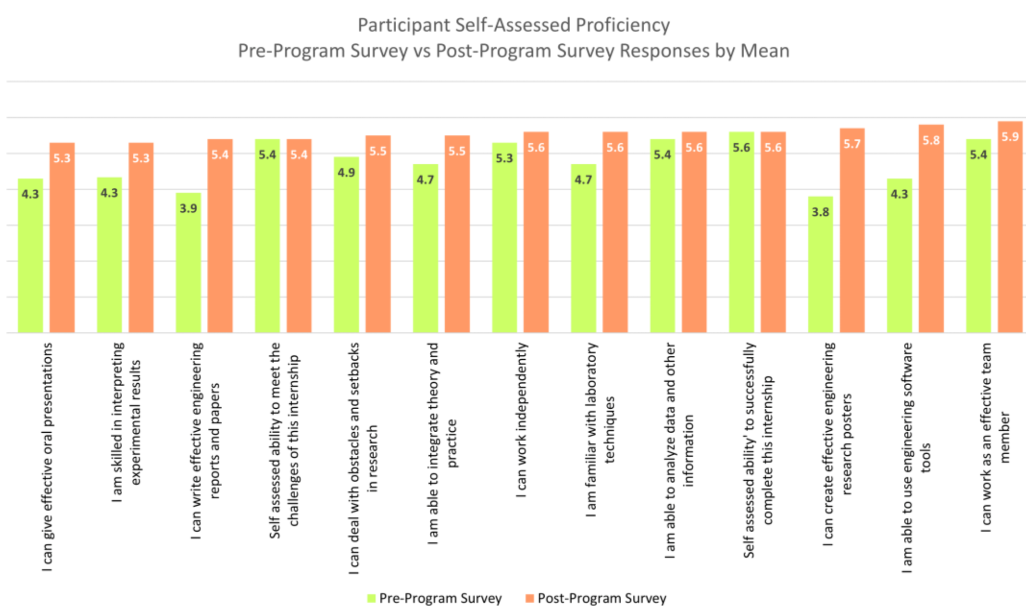

Figure 3. Results from the survey on student perceptions of self-accessed proficiency. Question: Please indicate your level of agreement with the following statements. (1-Strongly Disagree, 6-Strongly Agree)

The results of pre- and post-program surveys on student perceptions of research are presented in Figure 4. Prior to the internship, students agreed or slightly agreed with six out of the nine assessed items, and agreed or strongly agreed with the remaining three items. Following the program, students expressed increased agreement across all nine items compared to pre-program results. The most significant improvement was observed in understanding how engineering knowledge is constructed (from 4.2 to 5.4), followed by the ability to read and comprehend engineering publications (from 4.3 to 5.4), understanding how engineers solve real-world problems (from 4.4 to 5.4), and a greater interest in laboratory research as a potential career path (from 4.5 to 5.5).

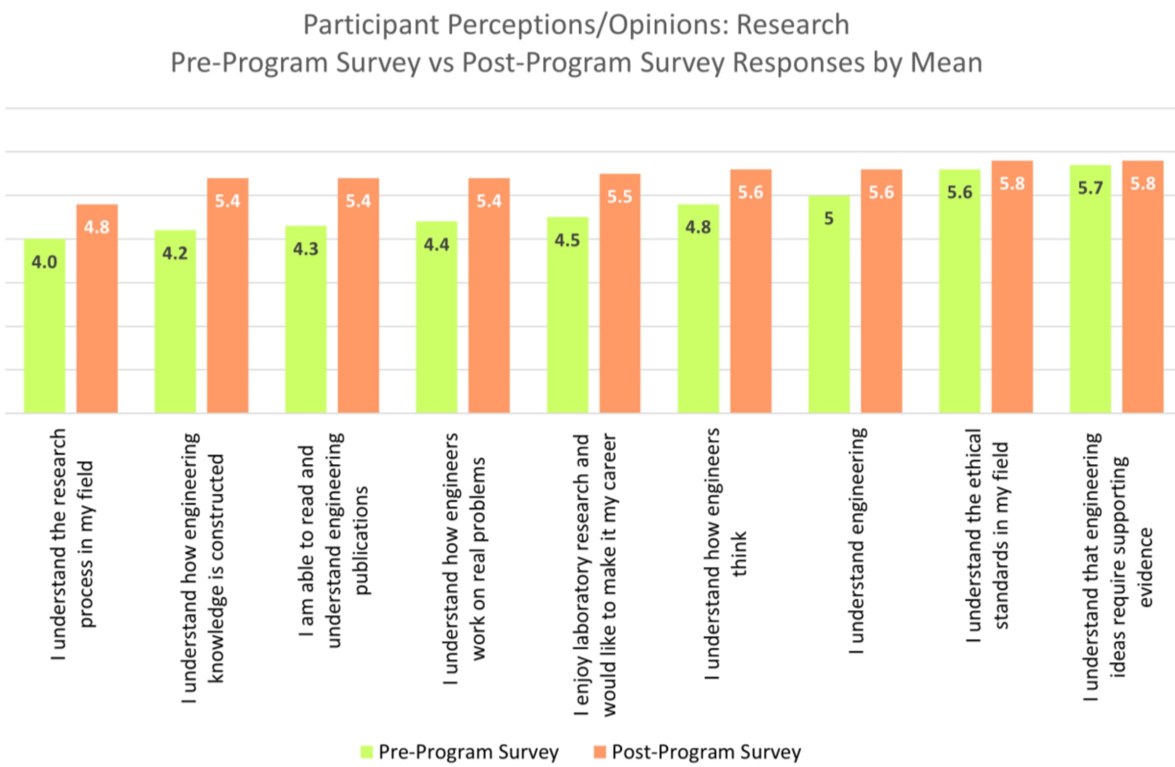

Figure 4. Results from the survey on student perceptions of research. Question: Please indicate your level of agreement with the following statements. (1-Strongly Disagree, 6-Strongly Agree)

The results of the post-program survey evaluating student perceptions of their internship experience are displayed in Figure 5. Overall, students had extremely positive feedback about their internship experience, agreeing or strongly agreeing with all ten items listed. Almost all the students strongly agreed that they enjoyed the internship and had many learning opportunities during the program. Although most of the students agreed or strongly agreed that they had regular meetings with their research supervisors, one student slightly disagreed with this statement.

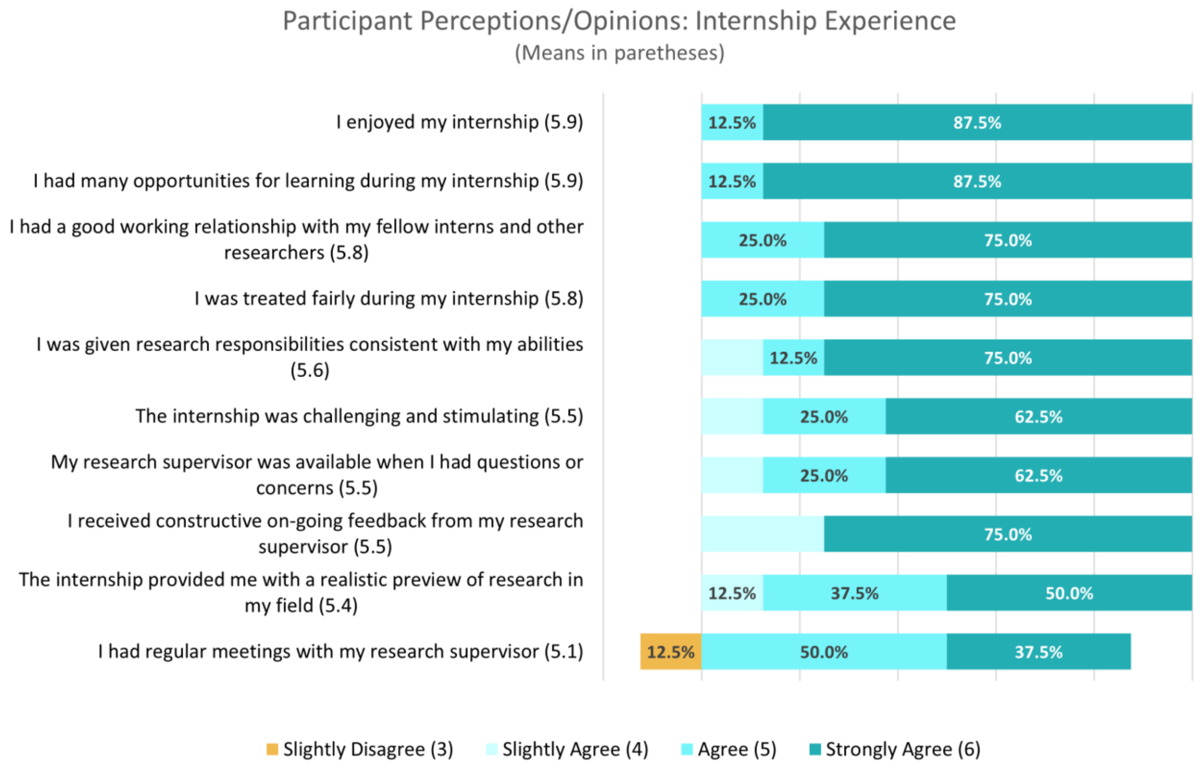

Figure 5. Results from the survey on student perceptions of education and career. Question: Please indicate your level of agreement with the following statements. (1-Strongly Disagree, 6-Strongly Agree)

Conclusion

The first-year implementation of the S-SMART Summer Research Internship program successfully provided opportunities for first- and second-year community college students, with a focus on those from URM groups, to engage in innovative engineering research, receive close mentorship from faculty advisors and student peer mentors, and acquire hands-on engineering skills in a collaborative research environment. The program's success in attracting URM and female students was demonstrated by their higher participation rates compared to overall engineering enrollments.

The pre- and post-program surveys demonstrated that the program boosted students' confidence in successfully transferring and earning a BS degree in engineering, facilitated a better understanding of career opportunities and pathways, and improved mental, communication, and lab skills. The research work done by the students has resulted in several student conference papers and poster presentations at professional conferences such as the American Society for Engineering Education Pacific Southwest Section (ASEE PSW) Conference, which is an uncommon achievement for first- and second-year undergraduate students, particularly in community colleges.

Although the first-year implementation of the S-SMART Summer Research Internship Program showed promise, several improvements have been implemented or will be for the next summer program. A program website has been developed with clearer instructions to better advertise the program and attract more applicants. The Qualtrics electronic application and recommendation forms have been modified for a more user-friendly interface to improve the application and review process. The SFSU faculty team will work more closely with community college coordinators to expand the promotion of the program to a larger student population, particularly those from URM groups. Besides survey-based quantitative methods, further analysis will be conducted on student interview data using qualitative methods to assess program outcomes. The feedback from the participants, peer mentors, and faculty advisors will also be reviewed and integrated to enhance future iterations of the program.

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