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Hybrid and Virtual Summer Research Experience for First- and Second-Year Computer Science Undergraduate Students

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Abstract:
The outbreak of COVID-19 has significantly disrupted university operations across the nation. Consequently, more than 90% of institutions had canceled in-person classes and moved to online-only instruction. However, this online-only teaching has raised additional concerns about the quality of instruction. Previous studies have shown that students' performance was negatively impacted by online learning. KIn contrast, current data shows a disproportionate burden of illness and death among racial and ethnic minority groups. There is a growing concern that COVID-19 has significantly impacted STEM education among minority groups. More specifically, throughout the COVID-19 pandemic, engaging students in research via online modality was a challenge. During summer 2021, research activities were undertaken by Engineering and Computer Science (ECS) undergraduate students virtually through the NSF-funded project "*Building Capacity: Advancing Student Success in Undergraduate Engineering and Computer Science (ASSURE-US).*" In Summer 2022, a new cohort of ECS students was accepted to conduct research in a hybrid modality. Here we present a comparative analysis of virtual instruction and hybrid instructional modalities implemented during the Summer Research Experiences for freshman, sophomore, and junior engineering and computer science students. The findings suggest a greater engagement of the students during the hybrid summer research in 2022 than in virtual summer research in 2021.

Keywords:
Summer research, computer science education, undergraduate research, hybrid modality, virtual modality

1. Introduction

The COVID-19 pandemic has affected all facets of life, including personal, professional, and academic life. Amidst this, engaging students and maintaining vibrant undergraduate research activities was challenging. One of the goals of the National Science Foundation (NSF)-funded grant, "*Building Capacity: Advancing Student Success in Undergraduate Engineering and Computer Science (ASSURE-US)*," (2018-2023), is to close the achievement gap and increase the retention of underrepresented minority (URM) students in STEM. The ASSURE-US project envisaged implementing a holistic, long-term, broad-based, result-oriented, and inclusive strategy to accomplish the goals. In 2018, NSF funded the ASSURE-US program for five-year to enhance learning experiences for first- and second-year URM students enrolled in the College of Engineering and Computer Science (ECS) at California State University, Fullerton (CSUF). The multi-pronged strategy implemented through ASSURE-US project activities aims to promote sociocultural interaction, demonstration-based learning experiences, and curriculum-related research experiences for the

URM students. Specific objectives include 1) creating a nurturing learning environment through the formation of the Student Teacher Interaction Council (STIC); 2) providing culturally meaningful learning experiences involving extensive laboratory and field experiments; 3) providing first-year research experiences to freshman engineering students to generate and sustain interest in STEM; 4) integrating research activities into curriculum to increase real-world relevance of research experiences; 5) and improving the analytical instrumentation and critical thinking skills of undergraduate students that could prepare them for graduate studies.

The multidisciplinary ASSURE-US project team has identified summer research as a possible avenue for students to gain meaningful experience and increase their motivation in their major, thereby promoting their retention. The Summer Research Experience (SRE) is a rigorous, collaborative, immersive, and hands-on learning experience offered by ECS faculty. The freshmen, sophomore, and junior students in ECS were teamed with ECS faculty for an uninterrupted 5-6 weeks (11 hours per week), incentivized (stipend-based) summer research. Faculty mentors were selected from multiple ECS majors: civil engineering (one faculty), computer engineering (two faculty), computer science (three faculty), and mechanical engineering (one faculty). Each faculty proposed various research topics for students to sign up for; however, students were allowed to choose only two topics.

The ASSURE-US project was initially designed for in-person, hands-on student engagement, including summer research activities. Due to the COVID-19 pandemic, in 2021, the ECS faculty conducted summer research activities in virtual mode. The hands-on, project-based research activities were redesigned to promote collaborative research in remote settings using virtual tools. In April 2021, freshmen, sophomore, and junior students in Computer Science were recruited by Dr. Bein to do research in a virtual setting. It was the first time for recruited students and Dr. Bein to conduct research virtually. The students followed a six-week intensive research program that allowed them to gain experience in Data Science, Python Programming, and familiarity with Jupyter Notebook and Microsoft Teams. In the Summer of 2022, a new cohort of first-year and second-year Computer Science students was selected in April 2022 to do research in a hybrid modality where students were expected to spend at least 25% of their time studying in one of the Computer Science labs. We observed a greater engagement of the students during the hybrid summer research in 2022 than in virtual summer research in 2021.

The paper is organized as follows: Section 2 presents a summary of similar work conducted elsewhere, Section 3 presents the student context at CSUF, the ECS, and the Computer Science Department specifically, since the vast majority of students doing summer research were from that department. The research methodology is presented in Section 4, followed by student outcomes in Section 5, student feedback in Section 6, and the conclusion in Section 7.

2. Related Work

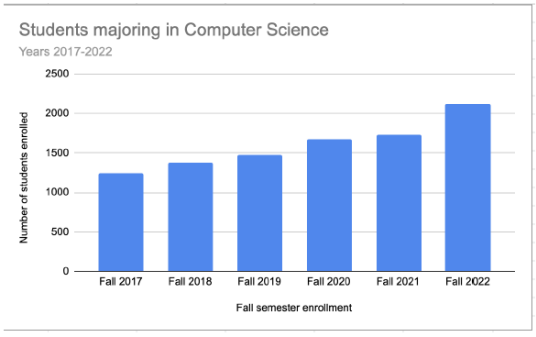
Previous studies [1] have shown that students' performance was negatively impacted due to online learning. Also, current data show a disproportionate burden of illness and death among racial and ethnic minority groups. Given that COVID-19 adversely impacted student engagement in online instructional modality, thereby significantly impacting STEM education among minority groups. Narrowing the achievement gap requires careful consideration of underlying causes that affect URM students'(Female, Hispanic, and African American) unequal participation in STEM disciplines. For students, often a combination of ethnicity, gender, sociocultural influences, academic experiences and preparation, cognitive, attitude/perceptions, institutional variables, and environmental factors affect not only their choice of majors but also their ability to perform and succeed in the chosen major [2][3]. Retaining students in STEM disciplines is challenging, particularly for low-income, first-generation minority youth who lack foundational skills and knowledge in the STEM fields [4]. Furthermore, multiple studies show that the informal communication and accessibility of faculty role models to provide moral, educational, and cultural support would ultimately result in students maintaining enthusiasm, confidence, and retention in STEM disciplines [5][6]. These studies reported that by building rapport, both the students and the faculty equally benefited.

3. Student Context at California State University Fullerton

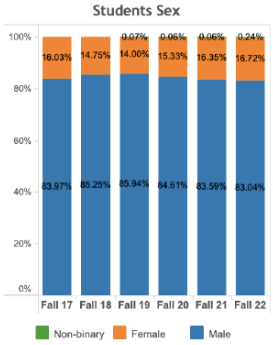
California State University, Fullerton (CSUF) is the largest of the 23 CSU campuses. CSUF is recognized as the No. 1 choice for transfer students from community colleges in California. Our student population is among the most diverse in California. CSUF is a recognized Hispanic Serving Institution (HSI) and an eligible Asian American Native American Pacific Islander Serving Institution (AANAPISI). Of the 40,000 students currently enrolled in CSUF, more than 65% of students are ethnic minorities, and nearly one-third of all CSUF students are first-generation college students.

CSUF offers 110-degree programs, of which 55 are undergraduate and 55 graduate programs, including doctoral degree programs in education and nursing practice. Many of these programs have achieved national prominence because of our outstanding faculty and alums achievements. Recently released U.S. News & World Report, in its 2022-23 Best Colleges rankings, praised Cal State Fullerton as a top "national university" offering a full range of undergraduate, master's, and doctoral programs and committed to producing groundbreaking research. U.S. News also ranked Cal State Fullerton at No. 7 of "Top Performers on Social Mobility" in the nation and No. 83 of "Top Public Schools" in the nation." These recognitions came after CSUF advanced to the "Doctoral Universities: High Research Activity" category by the Carnegie Classification of Institutions of Higher Education [7]. The Hispanic Outlook in Higher Education in October 2021 ranked CSUF first in California and fourth in the nation among top colleges and universities awarding bachelor's degrees to Hispanic students [8][9].

The Department of Computer Science has seen tremendous growth in the past five years (see Figure 1 a) and has doubled in size since 2016.



(a) Trend of student enrollment in B.S. in Computer Science



(b) Gender distribution of C.S. undergraduate students

Figure 1. Enrollment trend and gender distribution in the B.S. Computer Science program

The estimated U.S. gender ratio in 2020 was 49.48% male and 50.52% female [10], which is proportionately reflected in the computer science jobs in the tech industry, with 78.8% male and 21.2% female [11]. Efforts such as peer mentoring and informal advising of female C.S. students supported through ASSURE-US (NSF grant), private grants, and gift-in-kind donations from significant companies increased the percentage of female students from 14.76% in Fall 2018 to 16.72% in Fall 2022. However, the percentage of women majoring in Computer Science (see Figure 1b) is below the national average of 20% [12]. The race/ethnicity of C.S. students at CSUF (Figure 2a) represents the student population in California, and the percentage of underrepresented students shows a steady increase over the years (Fig 2b).

4. Research Methodology

There were three objectives for the summer research:

1. Engaging students in research through faculty-student meetings, promoting retention, and cultivating interests in their chosen major
2. Encouraging students' teamwork to promote student-student interaction, given that most of them did not know each other
3. Encouraging students to ask questions and delve deeper into specific topics. Being inexperienced in conducting research, students did not know when and how to ask for help.

Increasing participation of URM students was a critical aspect of the ASSURE-US project. The ASSURE-US project team reached out to active ECS student clubs such as the Society of Women Engineers, Association of Computing Machinery - Women in Computing, Latinos in Science and Engineering, National Society of Black Engineers, and Society of Hispanic Professional Engineers. With help from C.S. Department staff, individual recruitment of students from introductory ECS classes was performed during the regular semesters, Spring and Fall. We also invited all ASSURE-US student participants who had enrolled in the program as of Fall 2018. Students applied for each opportunity, and the faculty selected the students. Applicants were selected solely based on their academic status (freshmen, sophomores, and juniors) and not based on academic achievements. Because of NSF funding requirements, the students had to be U.S. permanent residents or citizens.

For the 2021 virtual summer research experience, the faculty mentor first prepared lectures, delivered synchronously on zoom, and shared relevant materials to initiate undergraduate students into research activities and familiarize students with the research objectives. These targeted lectures helped students learn the fundamentals of Python Programming, the use of Jupyter Notebook, choose appropriate datasets and analyze the dataset for a high degree of correlation. The faculty advisors helped students identify research topics such as air quality analysis, fraud detection for credit cards, drones, hardware accelerators, navigation, predicting heart failure, self-driving, voice-controlled robotics, or water potability.

The lectures were scheduled as follows:

- Two 90 minutes lectures in the first week: these lectures were dedicated to explaining the objectives of the research, the flexibility in choosing among the two topics, data science and pair trading, rules of studying and reporting progress, how and where to search for datasets, the supportive online materials available for further reading, how and when to ask for help with reporting worked hours, and allow each student to introduce themselves, talk about their interests in computer science and hobbies, what are their expectations,
- One 90-minute lecture in weeks 2, 3, and 4 to delve into the data science topic and allow students more time to study on their own, a total of two lectures for the two topics
- One sixty-minute meeting in weeks 5 and 6 for students to guide students into choosing a topic for the project, get further help on analyzing the data from the dataset, and report roadblocks,
- Two one-hour meetings in the last few days of the project were dedicated to voluntary oral presentations.

The faculty advisor also mentored and monitored the students' research activities using virtual tools such as Microsoft Teams and Zoom. These tools were used for meetings to track the student's research progress once or twice weekly. Furthermore, students were encouraged to work as a team to promote student-student and student-teacher interaction. For the summer 2022 hybrid summer research experience, the faculty mentor enhanced and delivered online lectures and shared relevant materials to initiate undergraduate students into research activities and familiarize them with the research objectives. The targeted lectures helped students learn the fundamentals of Python Programming, gain familiarity with Jupyter Notebook and select and analyze appropriate datasets for a high degree of correlation.

Additional topic on pairs trading was much more rigorous, requiring a review of data structures, Greedy method, recursion, parallel arrays, and learning about statistical variables such as standard mean, standard deviation, variance, correlation, and co-integration.

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- Two 90-minute lectures in the second week were dedicated to thoroughly analyzing two topics, emphasizing searching datasets for a data science topic. Four lectures were dedicated to two topics
- One 90-minute lecture for weeks 3 and 4 to delve into topics and allow students more time to study on their own, a total of two lectures for the two topics
- Two sixty-minute meetings for students to report roadblocks during weeks 5 and 6, irrespective of their topic
- A two-hour meeting for students was scheduled to make oral presentations voluntarily.

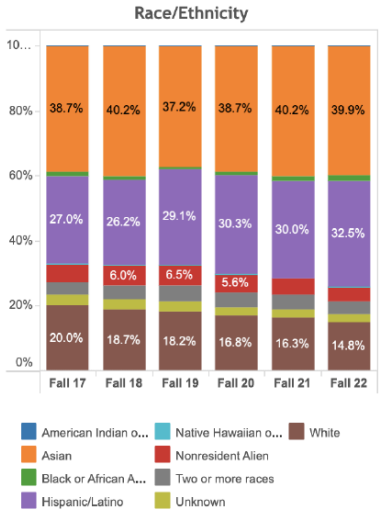
The students had to come to campus outside the synchronized virtual lectures to work with the peer mentors and socialize among themselves. The faculty advisor then helped students identify research topics such as student adaptability level in online education, student engagement at CSUF, data generation and analysis for League of Legends: Wild Rift, brain tumor MRI, analysis and prediction on real or fake job postings, correlation and co-integration of stocks for cryptocurrency, analysis of university students' mental health, and others.

5. Student Results

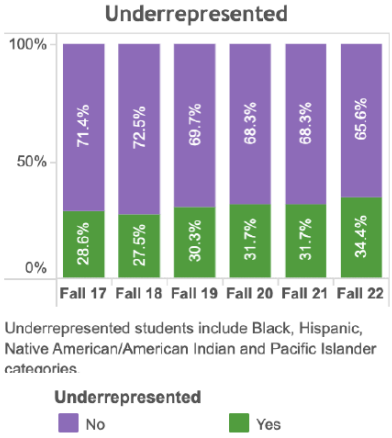
ASSURE-US project aims to motivate URM students by motivating them and supporting them through multiple academic and sociocultural intervention activities to help them persevere through ECS. The project activities created nurturing and supporting environment to enhance students' self-efficacy and desire to pursue STEM careers. The ASSURE-US project team sought to close the achievement gap and increase the pipeline of STEM-educated URM student populations by providing a holistic, long-term, broad-based, and results-oriented strategy. Rigorous laboratory and field research activities have boosted students' scientific understanding and offered an understanding of advanced science and engineering concepts in their respective disciplines. The faculty in Computer Science has dedicated effort to re-organizing the introductory courses and doing summer research with freshman, sophomore, and junior students that have applied.

Applicants were selected solely based on their academic status (freshmen, sophomores, and juniors) and not based on academic achievements. Of the 23 students participated in the summer 2021 virtual research program, 13 made oral presentations on their research findings using zoom. Of these, eight junior students preferred to work in groups. These students met with their teammates for the first time and were introduced during the weekly/bi-weekly meetings. Results of this summer research activity show that Microsoft Teams is a superior tool for organizing and managing the virtual student research experience. Overall, students expressed satisfaction with the experience, stating that this virtual undergraduate research experience helped them gain valuable experiences and better prepared them for the industry and higher education. Of the 26 students who participated in the summer 2022 hybrid research program, 24 made oral presentations on their research findings using zoom. Of these, ten junior students preferred to work in groups. These numbers show a greater engagement of students in hybrid research than in virtual research.

While academic achievement gap between URM and non-URM remains a concern, as evidenced by a large percentage of students repeating the lower-division courses. For example, during Fall 2021, despite



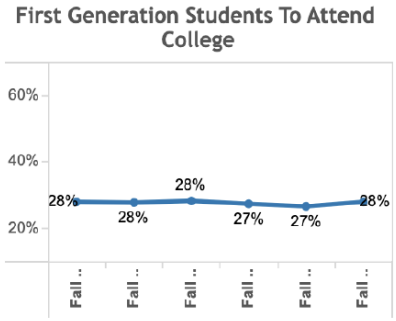
(a) Race/ethnicity in B.S. Computer Science program



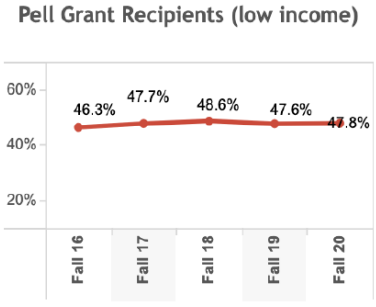
(b) Ratio of underrepresented students in the B.S. Computer Science

Figure 2. Distribution of Underrepresented groups in the B.S. in Computer Science program

In 2020, the estimated ethnic distribution of the U.S. population was 57.8% white, 18.7% Hispanic and Latino, 12.4% black or African American, and 6% Asian [13]. However, proportionate ethnic representation in STEM jobs is not evidenced, with an estimated 66.1% white, 25% Asian, and 5.2% Hispanic or Latino [4], and very different from the one reported at CSUF (Figure 2). Besides ethnic distribution, economic data shows that nearly half of CSFU students are Pell grant recipients due to low income (Figure 3b), and 28% are first-generation students (Figure 3a).



(a) the trend of first-gen students is stable at 27-28%



(b) the trend of Pell grant recipients is between 46.3-48.6%

Figure 3. Distribution of First-Generation Students and Pell grant recipients in the B.S. Computer Science program [15]

access to tutors and supplemental instruction, 26-34% of ECS students received a grade that required repetition of one or more introductory programming courses (CPSC 120, 121, 131). Compared to non-URM students and depending on the course, the repetition rate is 20-50% higher for URM students [14]. Worse, the retention rate for first-year C.S. students is 3-6 percentage points lower for URM students than non-URM students [15].

6. Student Feedback

In the summer 2022, the student survey responses showed that many students reported positive experiences: 41.2% were strongly positive, 52.9% were positive, and 5.9% were neutral. Students also reported a stronger commitment to the major: 47.1% strongly agree, 23.5% agree, 17.6% neutral, and 11.8% disagree. The data is shown in Figure 3.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree
I believe that I contributed something of value to the project Count Row %	6 40.0%	4 26.7%	4 26.7%	1 6.7%
My role involved doing real science, technology, engineering, or mathematics Count Row %	9 56.3%	6 37.5%	1 6.3%	0 0.0%
The results of my work were or will be incorporated into the larger research project that my research supports Count Row %	2 12.5%	4 25.0%	9 56.3%	1 6.3%
I enjoyed the summer research experience Count Row %	7 41.2%	9 52.9%	1 5.9%	0 0.0%
The SRE changed how I think about courses in my major Count Row %	6 35.3%	5 29.4%	4 23.5%	2 11.8%
As a result of the SRE, I am more committed to my major Count Row %	8 47.1%	4 23.5%	3 17.6%	2 11.8%

Fig. 3 Anonymous Data Collected from Students at the end of summer research 2021 by Arroyo Research Services

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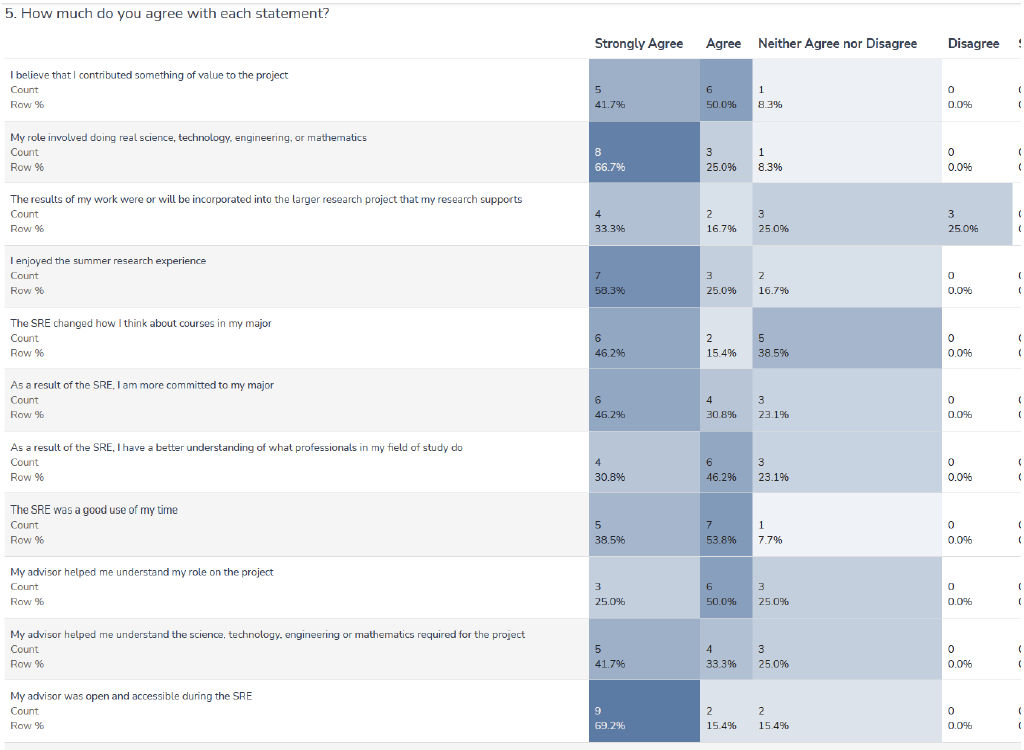
In summer 2022, the student survey responses showed a significant number of students reporting a positive experience: 50% were strongly positive, 25% were positive, and 25% were neutral. Students also reported a stronger commitment to their major: 50% strongly agree, 25% agree, and 25% neutral. The data is shown in Figure 4.



5. How much do you agree with each statement?

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree
I believe that I contributed something of value to the project Count Row %	5 41.7%	6 50.0%	1 8.3%	0 0.0%
My role involved doing real science, technology, engineering, or mathematics Count Row %	8 66.7%	3 25.0%	1 8.3%	0 0.0%
The results of my work were or will be incorporated into the larger research project that my research supports Count Row %	4 33.3%	2 16.7%	3 25.0%	3 25.0%
I enjoyed the summer research experience Count Row %	7 58.3%	3 25.0%	2 16.7%	0 0.0%
The SRE changed how I think about courses in my major Count Row %	6 46.2%	2 15.4%	5 38.5%	0 0.0%
As a result of the SRE, I am more committed to my major Count Row %	6 46.2%	4 30.8%	3 23.1%	0 0.0%
As a result of the SRE, I have a better understanding of what professionals in my field of study do Count Row %	4 30.8%	6 46.2%	3 23.1%	0 0.0%
The SRE was a good use of my time Count Row %	5 38.5%	7 53.8%	1 7.7%	0 0.0%
My advisor helped me understand my role on the project Count Row %	3 25.0%	6 50.0%	3 25.0%	0 0.0%
My advisor helped me understand the science, technology, engineering or mathematics required for the project Count Row %	5 41.7%	4 33.3%	3 25.0%	0 0.0%
My advisor was open and accessible during the SRE Count Row %	9 69.2%	2 15.4%	2 15.4%	0 0.0%

Fig. 4 Anonymous Data Collected from Students at the end of summer research 2022 by Arroyo Research Services

The students also reported what they had learned due to the summer experience. Selected students' answers are below:

- "Data science and linear algebra concepts"
- "I learned that as students, there are many ways outside of the classroom, that we can apply ourselves and learn. This SRE has definitely broadened my knowledge and motivated me to pursue my career."
- "I have started to learn Python, as well as data science, machine learning algorithms, pairs trading and data structures!"
- "I learned a lot about the advanced statistics such as co-integration and time series analysis"
- "I got more comfortable using data science tools."

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[14] https://mytab.fullerton.edu/#/views/CourseRepeatableGrades_0/CourseRepeatableGrades?:iid=1

[15] https://mytab.fullerton.edu/#/views/CollegeDepartmentSnapshot/StudentMajorProfiles?:iid=1

- "I learned how to do basic web scraping, manipulating json data, machine learning models via Tensorflow and Keras, and how to use Jupyter Notebook and matplotlib."
- "I learned about the different tools that are utilized in the world of Data Science."
- "I've learned to network with other professionals in their respective fields, used the research center at the library, and learned a new skill in coding."

The students' suggestions for improvement next year are right on target. Selected answers are below:

- "flexible meeting times"
- "What would help make this a stronger experience for all students is to encourage them to finish their projects and present their work. There is a lot more to learn by committing to their projects."
- "I really enjoy being in this program and I feel like SRE is a really good experience for me so I don't know how to make it even better!"
- "More group discussion and collaboration would be more enjoyable. Most students work alone."
- "Having more peer mentors and helpers would be nice."
- "Having the program helpers reach out and see how we're doing on our projects."

7. Conclusion

The conclusions from observing student behavior during the oral presentation and anonymous feedback show the impact of the ASSURE-US project's summer research activities. Student demonstrated immediate enhanced academic performance as evidenced by improved morale, self-efficacy, and grades. Through the oral demonstration of software projects on data science or pair trading, students became more aware of the value and importance of social capital (a set of shared values or resources that allows individuals to work together to achieve a common purpose effectively). The long-term implications of this study are an effective research-based teaching/learning education program that can be replicated at other HSI's science and engineering programs across the country. In Summer 2023, we intend to continue with a similar hybrid model to compare the students' success.

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