Positive Effects of Summer Research Program on Diverse Community College Students

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***Abstract*—Student participation in undergraduate research programs has been linked to improved content knowledge, skills, and confidence. However, few research opportunities exist for community college students. This study explores the positive effects of a summer research program on three diverse cohorts of such students. The Transfer-to-Excellence Research Experiences for Undergraduate program is a hands-on summer research internship for California community college students. The program seeks to inspire students to complete a Bachelor's degree in science or engineering and primarily serves identities underrepresented in those fields. Analysis of mixed methods evaluation data shows that after participating in the program, community college students were better able to find scholarly resources, design ethical scientific experiments, conduct independent research, and analyze data. Additionally, participation in the program enhanced students' science identity and confidence to pursue further education and careers in science and engineering fields.**

Keywords—engineering education, community college students, research program, student engagement

I. Background

Participation in hands-on research is an important part of most science and engineering students' undergraduate experience [1]. For students at four-year universities, these research experiences have been linked to enhanced understanding of the nature of science, scientific content knowledge, technical skills, and intellectual development [2]. Additionally, participation in undergraduate research clarifies students' career aspirations and plans to attend graduate school [3], [4]. For students from backgrounds underrepresented in science, technology, engineering, and mathematics (STEM), including students of color, women, and first generation college students, research experiences provide an additional benefit. Undergraduate research programs have been found to improve the self-efficacy of underrepresented students and remove barriers to their participation [5]. As such, it is important that all students have access to, and are encouraged to pursue, undergraduate research opportunities.

Community colleges are a crucial component of higher education in the United States. They provide students with broad and low-cost access to lower-division instruction. Because of their focus on teaching, community colleges offer little infrastructure for scientific research. This can severely limit students' access to hands-on learning and understanding of the scientific research process [6]. Acknowledging these limitations, several community colleges and four-year universities have recently developed research internships for community college students. To date, these programs have demonstrated success introducing community college students to scientific research. Hirst et al. [7] found that a collaborative program between a four-year university and a local community college enhanced community college students' research skills, increased their confidence, and facilitated their sense of inclusion in the scientific community. Similarly, Amelink et al. [8] determined that summer research programs are a successful way to develop engineering self-efficacy in community college students. These authors hoped that the expansion of similar programming would inspire more students to transfer to a four-year institution and complete Bachelor's degrees in STEM fields.

Community colleges enroll more students from underrepresented groups than their four-year counterparts, including ethnic minorities, financial aid recipients, students with disabilities, and re-entry students [9]. As such, successful involvement of community college students in scientific research is important for building diversity within the STEM fields. Better integration of this growing population will create a pipeline of qualified and engaged scientists throughout academia and industry. Given recent international investment in science, the United States must further grow its workforce if it is to continue to be a global leader. Ong et al. [10] write that ethnic minorities are an important part of that puzzle, holding large amounts of untapped talent and human capital. As the national need for diverse scientists and engineers grows, institutions must invest in programs that train community college students to conduct research and empower them to pursue careers in science and engineering.

The purpose study of this study was to establish a better understanding of the holistic impact of a summer research internship. This was explored by addressing the following research questions:

(1) How does a summer research internship affect community college students' understanding of the research process?

(2) How does a summer research internship affect community college students' research skills?

(3) How does a summer research internship affect community college students' confidence?

(4) How does a summer research internship affect community college students' career goals?

The findings of this study contribute to existing literature by providing a holistic review of the many impacts of a

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research program on community college students. Furthermore, the study specifically explores the experiences of participant cohorts with large ratios of students from backgrounds underrepresented in STEM. With this information, peer institutions and research agencies may consider establishing similar research opportunities for community college students. Should they decide to, the study provides a program framework that could be easily replicated.

II. Methods

A. Research Setting

The Transfer-to-Excellence Research Experiences for Undergraduates (TTE REU) program was founded at the University of California, Berkeley in 2012. The TTE REU program is intended to inspire California community college students to transfer to a four-year university and pursue a degree in science and engineering. Additionally, the program seeks to encourage participants to pursue further research opportunities and consider graduate studies in a STEM field.

Each summer, a cohort of California community college students completes a nine-week research internship in the laboratories of UC Berkeley professors. For most participants, this is their first experience with scientific research outside of lab-based college courses. As such, the program begins with a week-long boot camp to introduce them to the research process and develop skills necessary for engineering research. Following the boot camp, participants join their respective labs and each work on an independent research project in their intended field of study. These research projects span various STEM disciplines, including electrical engineering, computer science, material science, and physics. The participants interact with their host faculty member and are guided through their research by graduate student and/or postdoctoral mentors.

Participants' lab time is supplemented by weekly technical seminars and professional development workshops. These include presentations from faculty and students at the Center for Energy Efficient Electronics, and various industry partners. Recent lecture topics include "The Impact of Physics on Technology" by Dr. Eli Yablonovitch of UC Berkeley and "Electronic Innovation at the Atomic Scale" by Dr. Nerissa Draeger of Lam Research Corporation. The program participants also learn about financial aid, the transfer admissions process, and public speaking skills. By the end of the internship, each participant has written their transfer application personal statement essays and engaged in individualized transfer admissions advising with the Transfer Alliance Project.

At the conclusion of the internship, each participant writes a two-page research paper, creates a research poster, and shares a PowerPoint presentation about their project. Each year, a subset of participants are accepted to present their research at technical conferences, such as the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) Conference.

TTE REU participants live on-campus and receive a generous stipend and travel allowance. The program is funded by the National Science Foundation (Award #17576910) and the Center for Energy Efficient Electronics Science (Award #0939514).

TABLE I.

Underrepresented Identity	*Number of Participants*	*Percent of Sample*
Women	11	31.4%
First generation college students	16	45.7%
Underrepresented racial/ethnic minorities	12	34.3%
Pell Grant recipients	15	42.9%
At least one of the above	25	71.4%
Total	35	100%

Figure 1: Demographics of TTE REU participants, 2017-2019

B. Participants

The TTE REU program is open to California community college students with sufficient academic background in math and science. Applicants are required to have completed a year of calculus and three science or engineering courses, including one with a laboratory component. Furthermore, participants must be planning to apply for transfer to a four-year university the following year.

In the interest of broadening participation, students who are the first in their family to go to college, financial aid recipients, ethnic minorities, women, veterans, re-entry students, and students with disabilities are especially encouraged to apply. Program recruitment efforts include visiting community colleges with large populations of underrepresented students and collaborating with local offices of the Mathematics, Engineering & Science Achievement (MESA) program.

Students apply online and submit short personal statement essays, letters of recommendation, and sample course work. Participants are then selected by participating faculty and program staff. Cohorts consist of passionate, hard-working, and diverse students (Table I). This study considered the 2017-2019 cohorts.

C. Data Collection

This study explores the results of web-based pre-program and post-program evaluations completed by TTE REU interns. Evaluation validity was established by first reviewing existing tools that were used to assess student research experiences such as the Undergraduate Research Student Self-Assessment and others. Furthermore, the evaluation questions were adapted based on the literature about the needs and experiences of community college students. As the questions were adapted, they were piloted with a group of administrators and community college faculty, as well as a TTE REU cohort. Each group was asked to provide feedback on the perceived intent and phrasing of the questions. This feedback was used to further refine the tool. Following the pilot, a final tool was established and used with subsequent cohorts in order to provide longitudinal data regarding the survey questions. This study considers only those subsequent cohorts who used the final tool. The evaluations were administered by the research team through Qualtrics.com and took ten to thirty minutes each to complete.

During the program orientation, participants were led through an informational session that helped them understand how their honest and open responses are used to inform current and future program design. All participants were expected to respond to the evaluations as part of their program participation.

The pre-program evaluation was administered to the participants at least two weeks prior to the internship experience. This evaluation collected information about participant demographics, academic background, career goals and challenges related to meeting those goals, any prior research experience, and current level of confidence in laboratory and research skills. Participants were asked to rate their skills on a one to five scale and answer open ended questions in paragraph form.

The post-program evaluation was administered to the participants at the conclusion of the summer research experience. This evaluation collected information about their research projects, attitudes about general involvement in the program, current level of confidence in laboratory and research skills, attitudes toward science and science as a career, benefits and challenges of the experience, how the experience might affect future decisions about education and career path, and suggestions for program improvement. Participants were again asked to rate their skills on a one to five scale and answer open ended questions in paragraph form.

D. Data Analysis

a) Quantitative Data: A subset of fourteen questions that considered students' abilities and future plans were considered for this study. The research team calculated and compared the means of participants' scores on both the pre-program evaluation and post-program evaluation.

b) Qualitative Data: Qualitative data was gathered from open-ended questions included on the post-program evaluation. These questions asked participants to reflect on skills and knowledge gained from the summer research experience. Additional questions asked the participants to reflect on what they learned about themselves and others during the experience, to describe the challenges they faced during the summer, and to describe how the summer research internship did or did not meet their expectations. The trends seen in the quantitative data analysis informed the creation of a list a priori codes. Participants' responses to open ended questions were then reviewed and coded. During this coding process, confidence gains emerged as an additional theme.

c) Validity & Reliability: This study utilized a mixed methods approach to ensure results were both valid and reliable. The data triangulation process achieved through mixed methods evaluation produces "a more comprehensive set of findings" [11, p. 35]. Additionally, the study examined data over a three year period to account for different perspectives and experiences among participants.

E. Protection of Human Subjects

This study was reviewed and approved by the University of California, Berkeley Institutional Review Board (IRB) for the Protection of Human Subjects. All participants voluntarily completed an informed consent form and received a copy of the consent form for their own records. Identifying information was kept separate from evaluation data and is not included in this report.

F. Study Limitations

The scope of the Transfer-to-Excellence REU program is limited by available funding and staff capacity. As such, this study explores the experiences of a select sample of 35 community college students who participated in the program. In addition to the limitations of the sample size, study conclusions may be biased by the selective nature of the program. While the program staff aim to be as inclusive as possible, applicants are required to document that they are prepared for a scientific research experience. This includes receiving high grades in math and science courses, submitting letters of recommendation from instructors and community members, and providing sample coursework for staff and faculty review. As such, caution should be used when extrapolating the findings of this study to community college students with less preparation.

III. RESULTS

Participant feedback proves the Transfer-to-Excellence REU program to be a success; 94% of participants in the 2017-2019 cohorts rated their experience positively, with 80% indicating that they had a "very positive" experience. Participants have shared:

> This research experience unveiled a hidden layer of reality I formerly knew nothing about. Through this opportunity I improved on a multitude of skills: communication, public speaking, teamwork, self-motivation, time management, leadership, ability to work under pressure, the list goes on.

> I cannot wait to go to my college and talk about this program. I would advertise it a lot because it clarifies your goals, expectations, and information about pursuing a degree in STEM fields. That kind of information I could not get from my college or any of the STEM counselors at my college.

Furthermore, 94% of past program participants have since transferred to a four-year university to pursue a degree in science or engineering.

Quantitative and qualitative results were found to be very similar for each of the three cohorts studied. Only one measure varied for the 2018 cohort, as discussed in Section B.

A. Understanding of the Research Process

Given the scope of community college education and the lack of research experiences available on campuses, participants had a limited understanding of the academic research process prior to their arrival at the TTE REU program. After a one week engineering boot camp and eight weeks of hands-on research, participants ranked their understanding of the research process higher on three measures: understanding of the research process, ability to design experiments, and understanding of the ethical implications of research. Additionally, when asked what they gained from the experience, participants shared comments such as "I learned how to pose research questions and to make experimental designs to answer them" and

TABLE II.

Measure	*Mean Pre-program Rating*	*Mean Post-program Rating*	*Difference*
Understanding of the research process	3.34	4.17	0.83
Ability to design research experiments	2.94	3.77	0.89
Understanding of the ethical implications of research	3.28	4.17	0.83

Figure 2: Pre- and post-program survey data regarding understanding of the research process

> I did not have any idea about research. I have learned many things from here. For example, how to search for research topic, how to do research, what should I do if I do not get successful result[s], how to write a research paper, how to make [a] presentation and poster. In addition, my time managing skill[s], and my patience [has] increased and I have become more familiar with lab and work environment.

The participants' rating of their knowledge and abilities on a one to five scale appears in Table II.

B. Research Skills

Quantitative evaluation data shows self-reported gains in participants' ability to conduct research, including ability to understand academic sources, present their research findings, and technical and data analysis skills specific to their research project (Table III). In contrast to their peers, the 2018 cohort reported a decrease of 0.22 in their ability to analyze and interpret data after their participation in the program. While the reason for this discrepancy is not known, it is possible that participants gained a better understanding of the scope and complexity of data analysis and interpretation in the context of scientific research during their participation in the TTE REU program.

In response to open-ended evaluation questions, the participants discussed learning several new skills including finding and understanding journal articles. This is a skill many participants had struggled with prior to joining the TTE REU program:

> During this summer research, I learnt to read research paper[s] which I had been always afraid of. I learnt to identify research paper[s] that [are] relevant to my project. It was great to get over the fear of reading research papers, and I realized that I had always underestimated what I knew.

The participants also discussed gaining problem solving and technical skills through the experience:

> This research experience has helped me improve my problem-solving skills, gain knowledge about how to conduct research and knowledge on electronics in general.
>
> I also learned a great deal about graphene nanoribbons and the work that is being done to integrate them into digital electronics.

TABLE III.

Measure	*Mean Pre-program Rating*	*Mean Post-program Rating*	*Difference*
Ability to find resources on a scientific topic	3.34	4.08	0.66
Ability to synthesize and use information from diverse sources	3.37	4.03	0.66
Ability to analyze and integrate information from separate sources to solve complex problems	3.26	3.94	0.69
Ability to carry out research experiments	3.34	4.06	0.72
Familiarity with lab techniques and instrumentation	3.51	4.00	0.49
Ability to analyze and interpret data	3.63	4.00	0.37

Figure 3: Pre- and post-program survey data regarding research ability

> I learned how to perform electron beam lithography, use sa scanning electron microscope and Raman microscope. I also learned how to fabricate and characterize 2D crystals and design electrical devices to test the properties of 2D materials. While some of this does not necessarily relate to my major it was interesting to learn and may prove useful later on. Also, I learned about how labs function which is useful in any laboratory setting.

Finally, participants noted gains in their science communication skills, including their ability to present and publish their research results:

> I learned how to write a technical research paper as well as creating an effective poster. I learned how to conduct a literature review and properly compose an abstract.
>
> During this summer I was able to have the opportunities to present my research project in one of my department meeting[s] and several times in my lab group meetings. I can definitely feel myself keep improving.

C. Confidence Gains & Career Clarity

With a comprehensive understanding of the research process and a new-found skillset, participants reported feeling more confident. Additionally, the experience developed and reinforced their identities as scientists. One participant shared: "I learned that I do have a place in science. I learned that I am as capable in my major as many other students." Participants were excited to discuss the effects of the research program on their self-efficacy:

> I have learned that I am capable of a lot more than I have ever imagined. I was able to understand something that I have never heard of before this research and make it work so that my research would be successful.
>
> I've learned to have much more confidence in myself than I had before this program. I used to think I was not smart or good enough to be a scientist, but I see how incorrect

that is now. Researchers are all intelligent yes, but they are not all super geniuses. They are just people who like understanding the world around us.

Finally, the program clarified participants' choice of major and their transfer plans. For some, it empowered them to pursue graduate school and/or careers in science and engineering which they had either previously not considered or not thought possible:

> Finally, I gained confidence in my abilities and in my plans for the future.
>
> This program has helped me realize that I have a great passion for engineering and I now know that I want to pursue mechanical engineering for sure!
>
> Summer research has given me hands-on experience applying knowledge gained in class to solve real problems. It has also taught me critical thinking and problem solving skills and empowered me to want to pursue a PhD in software engineering.
>
> I had little desire to pursue a graduate degree before coming to this program and I am now completely certain that I will attend graduate school after I finish my bachelor's degree.

The participants' rating of their confidence and career clarity on a one to five scale appears in Table IV.

TABLE IV.

Measure	*Mean Pre-program Rating*	*Mean Post-program Rating*	*Difference*
I have had experiences that made me confident in my ability to perform tasks that will allow me to succeed as a student in science & engineering	4.14	4.57	0.43
Confidence in science & engineering ability	3.57	4.20	0.63
Clear career goal(s)	3.80	4.08	0.29
My summer research experience has influenced my future career choice	Not collected	4.43	N/A
My summer research experience has influenced my decision to pursue an undergraduate degree in science & engineering	Not collected	4.40	N/A

Figure 4: Pre- and post-program survey data regarding confidence and career clarity

IV. DISCUSSION

A. Understanding of the Research Process

As previously discussed, community colleges offer students little access to research opportunities. As a result, the TTE REU program participants arrived on campus with limited understanding of the research process and how to design research experiments. During the first week of the program, staff observed that students appeared quite panicked about the upcoming experience. As such, the TTE REU program began with an orientation and a week-long boot camp in which participants learned more about research through guest panels, lectures, and lab tours. For example, one lecture focused on conducting research ethically and was followed by role-play scenarios and peer discussion about ethical decision making. This introduction was intended to familiarize participants with the research process before they joined their individual labs.

Participants really began to understand the research process when they met their graduate student mentor and started working in their research lab. Because they each had their own independent research project, they were able to experience the research process from start to finish. This understanding may have been enhanced by attending lab meetings and technical seminars led by faculty. Finally, because they lived and socialized with others in the program, participants also learned about the research experiences of their peers in different research settings.

Moving forward, familiarity with the research process may enhance students' interactions with their coursework because they will be better able to understand how experiments were conducted and engage critically with the material. Designing experiments and conducting research is also a core component of graduate studies and professorship. Institutions must provide students with a clear understanding of the research process if they are to aspire to, or prepare for, these roles.

B. Research Skills

The participants received background articles about their research area prior to their arrival on campus. While these were intended to prepare participants for their research project, they often also panicked and intimidated them. Many were not familiar with the terms used in the literature and had never learned how to read an academic article. As such, a former participant led a workshop on reading unfamiliar articles during the boot camp week each summer. The participants then spent another couple of days working through the articles previously sent by their mentors. As the summer continued, they were required to read additional articles to better understand their project, write a literature review, and troubleshoot problems that arose. They were also required to write a two-page scientific paper that presented the results of their own project. Evaluation data shows that after participation in the program, students were more confident in their ability to find and read academic articles. This skill is important because it permits students to engage with material on a deeper level, facilitating long-term retention and "higher-order cognitive skills such as the ability to analyze, synthesize, solve problems, and [think] meta-cognitively" [12, p. 21].

Community college students' interactions with their science curriculum may often be limited to reading textbooks,

memorization, and pre-planned lab activities. By participating in scientific research, participants are able to actively engage with their field of study and create new knowledge. Often, research projects did not go as planned and participants may have made mistakes or experienced unexpected set-backs. Additionally, the TTE REU participants' faculty and graduate student mentors were not always readily available to provide assistance and troubleshoot. As such, participants were required to be resourceful and engage in creative problem solving. This finding is supported by qualitative evaluation data—participants shared that they learned how to work independently, manage their time, proceed from unsuccessful experiments, and ensure they did not repeat mistakes. Participants also discussed building resilience and learning how to be more forgiving of themselves when they did make mistakes. In addition to being important research skills, these will benefit the participants in many aspects of their lives.

With the exception of the 2018 cohort, participants reported that they were better able to analyze and interpret data after participation in the program. Once their project data was analyzed, participants presented it through three forms: a two-page research paper, a scientific poster, and a fifteen-minute PowerPoint presentation. Through the course of the summer, participants attended workshops on how to structure these presentations, observed more advanced students present, and then practiced presenting to their lab group and fellow participants. Through the qualitative evaluation measures, many participants discussed their enhanced science communication skills. These skills can be categorized into two groups: (1) understanding of scientific presentation methods and how to execute them professionally, and (2) public speaking skills and confidence. The latter was especially true for participants for whom English was not their native language.

Unsurprisingly, evaluation data also shows that the TTE REU program enhanced participants' technical skills. These skills varied, as participants conducted research in many different fields, but included coding, circuit building, electron microscopy, image processing in MATLAB, computer programming, and wet-lab skills. Mastery of these skills is especially important for community college students who wish to transfer to a four-year university. After transfer, students will have just two to three years to complete their coursework and prepare for graduate school or a technical career. Familiarity with research skills and techniques will help them quickly obtain and begin an undergraduate research position after transfer.

C. *Confidence Gains & Career Clarity*

Through the summer research experience and professional development programming, TTE REU participants developed a clearer understanding of the research process and advanced their problem solving and technical skills. Furthermore, quantitative and qualitative evaluation data shows that this experience enhanced participants' confidence, affirming the findings of Amelink et al. [8]. Additionally, the program developed participants' identities as engineers and scientists. Science identity, one's "compilation of level of interest, self-assessment of competency, and how much recognition one feels" has been found to be important to students' success [13, p. 5]. This is especially important in the TTE REU program because of the participant pool: individuals from backgrounds underrepresented in STEM. Research shows that these students may be less likely to have an existing science identity, and may find it more difficult to develop one. For example, researchers have found that forming a science identity can be especially tough for Black male students because of negative stereotypes about their race [14]. Similarly, science identity development has been proven to be difficult yet very important to the success of female high school students [15], and female scientists of color [10], [16]. These studies assert that students' identities as scientists must be recognized and supported by their instructors and community. The TTE REU program staff intend for the summer research experience and close mentoring relationships to provide this recognition and support for the diverse participants.

Quantitative evaluation data also indicates modest improvements in participants' self-reported career clarity. This is confirmed through participants' responses to open-ended questions. For example, a handful of students reported changing their intended major after hands-on interactions with a field. Additionally, participants shared that they felt more empowered and confident to pursue graduate school as a result of their experience. The program staff propose that this confidence gain is a composite result of participants' close interactions with current graduate students, enhanced self-efficacy, and reinforced science identity.

V. Conclusion

Quantitative and qualitative evaluation data confirm that the Transfer-to-Excellence program provides many benefits to community college students. Participants develop knowledge and skills that they may not have been able to practice at their community colleges, including an understanding of the research process and how to design experiments, the ability to read and understand academic articles, and field-specific technical skills. Participants also reported that the intensive research experience enhanced their science communication and creative problem solving skills. These gains will continue to serve participants in future research positions and throughout their academic careers.

Furthermore, this study found that participation in a summer research program can be a formative experience for community college students' science identities. This is important for several reasons. First, the development of a science identity may be especially difficult for community college students because their campuses lack research facilities, upper division courses, and graduate student role models. Additionally, these campuses educate more students from underrepresented backgrounds than four-year universities [9]. Existing research has found that students from backgrounds underrepresented in STEM may find it more difficult to develop their identities as scientists than their dominant-identity peers [14], [15], [16]. This is significant because science identity has been linked to commitment to remain in the science field [13], [17] and graduate school matriculation [18]. The findings of this study establish research internships as a successful tool for enhancing the science identities of students from underrepresented backgrounds. Therefore, institutions should develop such programming as they work to recruit, retain, and improve the campus experiences of underrepresented students.

After participating in the TTE REU program, students reported higher levels of confidence in their ability to transfer to a four-year university, pursue graduate studies, and plan careers in science and engineering fields. This is especially impactful because of the diversity of the community college population. Introducing community college students to research and empowering them to pursue STEM careers will further shared goals of racial, gender, and class equity within the science and engineering fields. This is important if the United States wishes to sustain an adequate pool of qualified employees and maintain its status as an international competitor [10]. Ethically, it is also the right thing to do. By further developing and funding research internships, institutions and national agencies can empower increased numbers and diversity of students to pursue graduate studies and careers in science and engineering.

The positive holistic effects of the Transfer-to-Excellence REU program can be mirrored by expanding research opportunities for community college students. The research team encourages administrators and faculty to create and fund research programs that account for the unique needs of community college students, and to explore additional partnerships with local campuses. The Transfer-to-Excellence REU could serve as a successful model for institutions wishing to develop such programming.

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