Development of a Multidisciplinary Summer Research Program for Community College Students in Science and Engineering

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Abstract

Community colleges typically enroll a greater percentage of minority populations and often provide a gateway to workforce development and four-year degree attainment. The aforementioned trends point to the importance of improving the matriculation and transfer of community college students into four-year science and engineering degree programs, especially in the field of engineering where African Americans, Hispanics, Native Americans, and females are underrepresented. However, literature notes that it is important that community college students are exposed to coursework and experiences that adequately prepare them for success at a four-year institution. This paper describes the multidisciplinary summer research program for community college students in science and engineering that is offered in the college of engineering at the University of California, Berkeley. This program was designed to prepare selected student participants for enrollment in a four-year institution within the University of California system. This paper also describes the comprehensive evaluation methods that were used to determine whether the summer program reached the intended aims and goals. Initial findings indicate that the program was successful with preparing students to transfer to a four-year institution as academic goals were clarified and the self-efficacy of students was improved. The outcomes of the evaluation results discuss how to refine the program for future offerings and how other institutions and programs can use this community college program framework to develop similar experiences and how to assess those programs for efficacy.

Introduction

To continue advancement in energy science and research and to thrive in a global economy, the U.S. will have to rely on scientists and engineers to develop innovative and high-value-added products and services, as well as improve productivity through the use of technology-based tools.¹ This pipeline of scientists and engineers, with its under-representation of women and underrepresented minorities (African Americans, American Indians or Alaskan Natives, and Hispanic Americans), is a critical concern for the U.S.² In 2010, the National Academies of Science reported that underrepresented minorities “embody a vastly underused resource and a lost opportunity for meeting our nation’s technology needs”.³ With today’s society facing global challenges in energy that are essential to sustaining our current way of life, it is even more critical for 4-year institutions to reach out to pools of students traditionally underrepresented in science and engineering programs.

One pool of such students is community college students pursuing math, chemistry, and physics courses that are transferrable to baccalaureate programs. In A Strategy for American Innovation, the Obama administration stated that “President Obama is taking continuous steps to improve our educational system ... and to promote student achievement and careers in STEM fields”, and “the Administration is committed to restoring America’s global leadership in college graduation rates, making investments in community colleges”.^{4,5} With more resources being allocated to community colleges to stimulate student achievement in STEM fields, and community

colleges serving many ethnic and racial minorities, community college students are uniquely positioned to fill the pipeline of STEM professionals.

With enrollment in the nation's community colleges hitting an all-time high, students from these institutions are a rich source of the nation's recipients of undergraduate and graduate degrees in STEM fields. The community college transfer pathway is particularly important for African American, Hispanic and Native American STEM degree recipients, as well as low-income students due to its low cost (\$36/unit).⁶ In this time of high unemployment and economic crisis, as in earlier recessions, community college enrollment has surged. During the 2009-2010 academic year, California alone enrolled 2.7 million students. The California Community College System (CCCS) is the largest community college system in the U.S., serving 25% of the nation's community college students.⁷ Of the students enrolled for 2009-2010, 40% were from NSF-categorized underrepresented minority backgrounds. In fall 2009, nearly 50,000 CCCS students transferred to University of California (UC) or California State University (CSU) campuses.⁸ One year earlier, nearly 20% (3,344) of all UC B.S. degrees in STEM fields were earned by community college transfer students, but only 11% (356) of these transfer graduates were from underrepresented minority backgrounds; 40% were women.⁶

Given these statistics, the primary goal of the community college research program described in this paper is to tap into the rich and diverse community college student body to produce the future STEM workforce. This framework explained is one that be adapted by four-year institutions targeting community college students.

Program Overview

UC Berkeley's Transfer-to-Excellence Research Experiences for Undergraduates program (TTE REU) provides research experiences to undergraduate students, specifically, community college students interested in pursuing a bachelor's degree in science and engineering. Created in 2012, this multi-disciplinary summer undergraduate research program is hosted by three centers funded by the National Science Foundation, Center for Energy Efficient Electronics Science (E3S), Center of Integrated Nanomechanical Systems (COINS), and Synthetic Biology Engineering Research Center (SynBERC) at UC Berkeley. Together, these NSF-funded centers program objectives are to provide TTE REU participants: 1) challenging science and engineering research projects in leading edge research laboratories; 2) advising to prepare students to transfer to competitive 4-year colleges/universities in science and engineering majors; 3) enrichment activities to build students' confidence to continue in science and engineering; and 4) exposure to the diversity of professional career opportunities that apply science and engineering training. Additionally, the program collaborates with UC Berkeley's Transfer Alliance Project (TAP). TAP provides individualized academic and transfer advising and enrichment programs that prepare community colleges students to be competitive applicants to four-year colleges.

Theoretical Framework

To provide a comprehensive experience for community college students, the TTE REU adapted the Branford, Brown, and Cocking's "How People Learn" (HPL) framework to design an inclusive, supportive, and effective environment for community college students. This HPL framework, consisting of four overlapping lenses, is displayed in Figure 1 and explained below.

Learner-centered Student Activities: Many community college students have unique challenges, as they are often low-income, the first in their family to go to college, and have not been exposed to the resources or opportunities to pursue careers in science and engineering. At the same time, they are often more focused and mature than typical 4-year students, as they have succeeded academically while working full-time and fulfilling significant family responsibilities. Given the diversity of community college students, TTE REU was tailored to meet the needs of the individual student rather than offering a “one size fits all” program. The built-in learner-centered components tailored to these students’ unique needs are as follows:

- i. **Application process** - During the application process, students provide their transcripts and write a personal statement describing their career goals, academic interests, and program expectations. The project team uses this information to match the selected participants to an appropriate faculty mentor, who then identify a graduate student mentor and design a project to meet the academic interests, background knowledge and course training of the individual community college students.
- ii. **Pre-program** - Before each class of the TTE REU Site begins, faculty and graduate student mentors participate in a mentor training to: 1) discuss mentor and participant expectations; 2) learn more about the community college cohort, including background, experience, and interests; 3) discuss best practices in mentoring for community college students, underrepresented minorities, women, and first-generation college students; and 4) receive guidance on the creation of a 2-page project summary. Prior to the students’ arrival, they receive their 2-page project summary and are contacted by their faculty and graduate student mentors to discuss their summer project, answer questions, and receive additional background material that will enhance their knowledge of the project prior to their first day in the laboratory.
- iii. **Orientation** - At the beginning of program, students participate in a rigorous 2-day orientation to bring the entire cohort to a shared understanding of: research, scientific ethics, laboratory safety, conducting literature reviews, data treatment and analysis, UC Berkeley’s campus and resources, and energy-themed research at the three hosting NSF-funded Centers.
- iv. **Growth seminars** - Growth is one of two themes for the seminars; Energy is the second. Growth seminars focus on academic, professional, and personal development and are tailored for community college students who plan to transfer to a 4-year college/institution to pursue a degree in science or engineering. These seminars are conducted by various faculty members, graduate students, and staff. Examples of presentation topics include: The Journey from Community College to Professional Success (panel); Tailoring your Technical Talk: Skill Building and How to Use PowerPoint; Uncovering the Diversity of Career Paths in the STEM Field (panel); Writing a Scientific Paper: The Outline, Audience, Sections, and Referencing; Continuing the Research Journey: Finding and Preparing to be Competitive for Research Programs after your REU; and Preparing for and Funding College and Graduate School.
- v. **Transfer advising and counseling** - TAP provides one-on-one advising to ensure that students select and complete the courses they need to be competitive applicants at competitive 4-year institutions. During the summer, participants receive bi-weekly

advising and monitoring of academic progress, as well as assistance in preparation of transfer admissions application and statement of purpose for 4-year institutions. After completion of the summer experience, TTE REU students continue to have access to advising and counseling as needed to successfully complete their college admissions application in the fall semester/quarter following their summer experience.

- vi. Individual meetings/individual development plans - TTE REU students meet weekly with their respective E3S, COINS, or SynBERC Educational Director. These one-on-one meetings are used to discuss the student's goals and accomplishments, monitor the student's research progress, and provide support outside of the research environment. All of the student's goals and accomplishments are tracked weekly using an individual development plan that the educational director and student develop together during their first individual meeting.
- vii. Weekly research journals - TTE REU students complete weekly research journals. Each week, the students are given a question to answer in their journal entry. This semi-structured format provides meager guidance, but also provides students the flexibility to reflect on their overall research experience. These journals are reviewed by the respective E3S, COINS, or SynBERC Educational Director and used to monitor the student's research progress and provide support outside of the research environment. In addition, these student thoughts are kept confidential among the program staff so that students have a safe haven to express and share their feelings freely.

Knowledge-centered Student Activities: The TTE REU program provides a rigorous research experience, where students are engaged in experimental design, execution, and analysis. The knowledge-centered components of the program are as follows:

- i. Supervised independent research experience - TTE REU participants join their faculty and graduate mentor in the research laboratory full time for eight weeks (minimum of 40 hours per week) for hands-on energy related projects. Every faculty and graduate student mentor has frequent contact with their community college researcher through their research meetings, one-on-one mentoring meetings, and TTE REU-sponsored activities.
- ii. Energy seminars - Energy seminars, part of our weekly Growth and Energy Seminars, consist of presentations by UC Berkeley's faculty on cutting-edge energy-related topics. The purpose of the energy seminars is to expose students to the diversity of professional career opportunities for people with science and engineering training.
- iii. Career day - The program hosts at least one industry-sponsored tour. Career day provides exposure to practicing scientists and engineers and the opportunity to learn about science and engineering careers in private industry and research laboratories.
- iv. Leadership day - TTE REU students participate in one leadership event. Leadership day provides students hands-on training on critical leadership skills and a leadership experience to contribute to their growth and help them become responsible citizens and leaders in their field.
- v. Work-in-Progress (WIP) meetings - Students participate in weekly WIP meetings as a cohort with the team of E3S, COINS, SynBERC educational directors. This activity provides each TTE REU participant an opportunity to present their recent research results to other TTE REU participants, share their research experiences, and jointly discuss their various projects.
- vi. Paper, poster, and presentation - The program concludes with a research symposium,

where each participant makes a 15-minute presentation on their project and participates in a poster session open to the UC Berkeley's community and invited guests external to the university. At the end of the program, all TTE REU participants submit a research paper that they are encouraged to submit to conferences.

- vii. REU as an independent study course - The students are enrolled in a UC Berkeley pass/fail credited independent study course with the program director as the instructor. Upon request by the student, UC Berkeley provides a transcript with the student's grade for the course. The student is allowed to submit their Berkeley transcript with this course as part of his/her academic record in the transfer application to a baccalaureate program.

Community-centered Student Activities: Building a sense of community as a cohort of high-achieving community college students is another key component to the TTE REU Site. The community-centered components are as follows:

- i. Residential housing - To promote camaraderie, students reside and eat together in the International House (I-House), conveniently located on the UC Berkeley campus. This residential program offers an essential experience for community college students as part of the preparation for a baccalaureate program. As community colleges students typically live at home while attending school, this experience likely offer most students their first full-time experience in networking, sharing, teaming and bonding with strangers in a close setting. TAP counselors are also on hand to support these students as they experience residential campus life for the first time.
- ii. Community building events - Throughout the 8-week program, students participate in community building activities as a cohort and with other REU and summer research programs on campus (e.g., Berkeley Engineering REU BBQ, Experience the Bay Tour). The aforementioned growth and energy seminars also serve as community building events.
- iii. TTE REU workspace - Each TTE REU student is provided a rented laptop over the summer to complete research and program requirements. To support their efforts outside of the research laboratory, the TTE REU students have designated workspace in Sutardja Dai Hall, where the Center for E³S is headquartered and both the E3S and COINS Educational Directors have their office. Students have free access to the internet and a printer/copier.

Assessment-centered Student Activities: Ongoing evaluation is key to addressing the needs of the community college students, faculty and graduate mentors, and program staff, and making any necessary improvements to managing the project, programming, and implementation of TTE REU. The program uses a formal mixed-methods evaluation process to measure the success and efficacy of the program. Evaluation for program participants is two-fold, including a formative and summative component. The formative evaluation, which is carried out to ensure the cohort is progressing as planned, includes the mid-term survey, weekly research journals, and one-on-one and WIP meetings. The summative evaluation, which includes the pre- and post-surveys, evaluation rubrics, exit interviews, and data tracking, is completed at the conclusion of each TTE REU class to measure the impact of the program and the extent to which it has helped achieve program and participant goals. Both the formative and summative evaluation combine quantitative and qualitative methods. Quantitative methods include surveys and evaluation rubrics with Likert-type rating scales. Qualitative methods consist of one-on-one and group

interviews and observations through the students' weekly research journals.

2012 TTE REU Program

TTE REU provides research opportunities addressing the need for a clean energy revolution and accelerating biotechnology and nanotechnology research and development. Using research as the catalyst for engagement, TTE REU supports a cohort of community college students from the California Community College System. For eight weeks, each TTE intern is paired with two mentors, a faculty member and a graduate student or postdoc from E³S, COINS, or SynBERC, who guide the student in independent research activities at laboratory meetings and through one-on-one mentoring meetings.

In 2012, TTE REU consisted of an 8-week residential program, including various pre- and post-program activities. The majority of the first week of our on-campus program focused on acclimating the students to a 4-year university environment and familiarizing them with expectations for their summer research experience. Students participated in a research orientation that covers the following topics:

- Utilizing Berkeley's Library System
- Strategies for Reviewing Technical Journals and Articles
- Maintaining your Research Notebook
- Scientific and Research Ethics
- Data Analysis and Research Results
- Safety Training for Laboratory Success
- Overview of Transfer Admissions and Requirement

During the remaining program, the summer researchers worked with faculty members and their graduate or postdoc, rejoining the cohort of TTE REU participants for regular meetings on topics that provide them more knowledge about science and engineering careers (e.g., science and engineering career panel, IBM and Joint Bioenergy Institute field trips, research seminars), help them prepare/acclimate them to transferring to a 4-year institution (e.g., meetings with department advisors and former community college, seminars on scholarships, writing personal statements, and transfer application process), and further develop their professional skills (e.g., seminar on writing scientific papers, giving technical presentations, and science communication).

Method

Participants

The 2012 TTE REU Program had 14 participants, all who expressed an interest in transferring to a 4-year institution to pursue a bachelor's degree in science or engineering. Each of these participants met the minimum requirements for the program: 1) 3.25 grade point average or

higher for science, engineering, and math courses; completed two calculus courses; and completed three science or engineering courses, one of which had a laboratory component.

Program Assessment

A mixed methods approach using formative and summative evaluation measures was used to assess the summer experience. First learning and program outcomes were identified for the summer experience. Based on those outcomes and the experiences that were going to be offered to students during the summer, questions were designed to gauge several different aspects of the program.

A pre-survey was administered to the students one week prior to their arrival on the Berkeley campus. The survey asked students about their degree aspirations, knowledge about the admissions process for enrollment at a four-year institution, confidence related to whether they thought they would be successful at a four-year institution, and long-term career goals. Students' perceptions about whether they had the needed criteria for admittance to and success at a four-year institution were also solicited. Questions asked participants about the clarity of the academic and career goals. Participants were also asked to rate themselves on key skills in comparison to peers including leadership, research, critical thinking, teamwork, and communication skills. A series of questions were also designed to capture students' research self-efficacy and were based on the four domains associated with this construct. Demographics about participants were also collected including income level, race, and gender. Students were also asked to name the top three institutions that they wanted to apply to and asked why they wanted to participate in the summer research experience. The post-survey asked similar questions of the participants so that gains over the summer could be measured in key areas that the program was designed to develop or enhance among participants. In addition, there were several questions that asked students about their experience over the summer and the satisfaction that they received in relation to mentoring and support from the program staff. Additional questions included an open-ended question that asked them what they learned over the summer.

In addition to the pre- and post-survey, there were also online weekly program surveys that asked about students' satisfaction with the programs and seminars that were offered. The interns were given 4 days to complete the survey. At the middle of the semester they were asked to complete a survey that asked them about their experience over the summer thus far and the satisfaction that they received in relation to mentoring and support from the program staff. This information was collected in order to provide immediate feedback to program staff so that adjustments could be made in programming for the students.

End of program focus groups were held with the interns in the second to final week of the summer program. The focus groups were designed to illicit more detailed information about how the summer experience helped them develop, specific challenges they faced and what they did to address those challenges, and specific examples of what experiences helped them feel more confident in their research skills as well how the experience might have impacted their academic and career goals.

Mentors were given an opportunity to report on mentees progress at the middle of the summer program via an online survey with primarily open-ended questions. At the end of the experience

the mentors were also asked to complete an online survey that asked what challenges mentees faced and what affective and cognitive skills mentees developed during the summer.

The survey results once collected online were summarized and reported to the program director. The mid-term results and end of program results provided by the interns as well as the mentors were broken down by disciplinary focus and shared with the respective education leaders. Focus groups were summarized via field notes and themes that emerged were highlighted via open coding. The findings were included in the final report.

Discussion

In total, there was a diverse group of participants in the TTE REU program (Table 1). In addition to the gender and racial/ethnic diversity, there were two veterans that participated and eight of the students were first-generation college students.

Table 1. Demographics of REU Students (n=14)

Demographic Indicator		N
Gender	Male	11
	Female	3
Ethnicity	Not Hispanic or Latino	11
	Hispanic or Latino	1
Race	American Indian	1 (7.1%)
	Asian	4 (28.6%)
	Black or African American	4 (28.6%)
	Native Hawaiian or other	-
	Pacific Islander	
	White	4 (28.6%)
	Decline to State	1 (7.1%)

Our results show that the program achieved the stated aims and goals as interns report measurable gains in engineering self-efficacy (Table 2). These gains were seen across the different domain areas related to self-efficacy.

Table 2. Engineering Self-Efficacy (n=14)

	Mean Score Pre-Survey	Mean Score Post-Survey
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 and engineering.	3.75	4.46
I have had the opportunity to watch and work with others and have seen them perform tasks that I will need to perform in order to succeed as a student in science and engineering.	3.27	4.30

I have received positive feedback about tasks I expect I will need to perform in the future to succeed as a student in science and engineering.	3.45	4.30
I have experienced a lot of anxiety or nervousness about tasks that are related to success as a student in science and engineering.	3.55	3.61

*Mean score based on scale of 1(Strongly Disagree) – 5(Strongly Agree)

In addition, interns reported gains in content knowledge, confidence in conducting research and presenting research through presentations following the summer research experience. They also reported gains in communication and leadership skills as they apply to research environments. The pre- and post-survey included additional questions but examples of students self-reported gains in these areas are provided in Table 3.

Table 3. Rating of Research, Laboratory Skills, and Academic Skills (n=14)

	Mean Score Pre-Survey	Mean Score Post-Survey
Knowledge of bioengineering and synthetic biology, nanotechnology and sensing environmental conditions, OR energy efficient electronics science	3.69	4.07
Understanding of the research process	2.69	3.92
Ability to make academic presentations	3.50	3.76
Initiative to solve engineering and science related problems	4.21	4.30
Ability to carry out research experiments	3.62	4.15

*Mean score based on scale of 1(Well Below Average) – 5(Well Above Average)

The summer experience helped clarify academic and long-term career goals for the students; post-survey responses were more focused with an increased number of students indicating they plan to transfer to a four-year institution and pursue a degree in a science related field. Interns reported being more confident that they knew how to apply to a four-year institution and remained confident that they could succeed in a four-year institution following the summer experience. Many students indicated that they saw this summer research experience as a major strength in helping them transfer successfully into a four-year institution. Students indicated increased knowledge about the admissions process and requirements for admissions following the experience.

Qualitative data gathered from the exit focus group interviews reinforced the quantitative findings and helped provide additional context for understanding the impact of the program on the interns. For instance, although many of the interns explained they knew about the transfer process, the REU was most valuable for helping them understand “what they needed to know and be able to do once they enrolled at a four year institution.” In terms of level of comfort with conducting research now that they are at the end of the experience, students explained that they “are less afraid of making mistakes” and see “mistakes as a good thing.” Interns also explained that this experience opened their eyes to what it would be like to work in a lab setting and gave them a better understanding of different roles people have (e.g., what a PI might do and how that differs from a faculty members/mentor).

Challenges cited by students included language barriers, both daily communication but also technical language skills needed for academic settings; not having the academic preparation that might be needed to “jump into” their project, and lack of knowledge about how a lab works in terms of equipment that they were using but also how it is managed and different roles people have. One student explained that “you don’t see students parked in the library for hours at my community college, focused on what they are doing...they may be at the library, but they are on Facebook and goofing off.”

Overall, while challenges were identified, many of which are inherent in a research setting, the students felt confident they gained the skills necessary to address those challenges in the future through this experience. Students were satisfied overall with the support and mentoring they received from mentors, program director, and program staff.

Conclusion

Community college students are a vital source of future scientists and engineers to meet the needs of the U.S. workforce. To increase the number of community college students who transfer to four-year institutions, summer research programs such as a TTE REU provide opportunities to expose students to available science and engineering careers, enhance their confidence to pursue bachelor’s degrees science and engineering, and offer transfer advising support to improve the students transition from community college to a 4-year university. This paper presented a framework that can be adapted by four-year institutions attracting community college students as transfer students.

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