Transfer-to-Excellence: Research Experiences for Undergraduates at California Community Colleges

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Abstract

The Transfer-to-Excellence Research Experience for Undergraduates program (TTE REU) is a multi-disciplinary summer undergraduate research program hosted by three NSF-funded centers, the Center for Energy Efficient Electronics Science, the Center of Integrated Nanomechanical Systems, and the Synthetic Biology Engineering Research Center at the University of California, Berkeley. Together, these NSF-funded Centers' cutting edge research programs are addressing the need for an energy revolution and accelerating advancements in biotechnology and nanotechnology. Using research as the catalyst for engagement, the TTE REU program has supported 30 community college students from the California Community College System. During the nine-week summer program, each TTE participant is paired with two mentors, a faculty advisor and graduate student mentor, who oversee and guide the student in independent research activities, through regular research group meetings and one-on-one discussions. Outside of their independent research projects, TTE participants are trained in research protocol, laboratory safety, and professional ethics; and participate in academic and professional development activities to prepare for a baccalaureate degree and career in science and engineering. The TTE REU program also partners with the UC Berkeley's Transfer Alliance Project, which provides individualized academic and transfer advising and enrichment programs that prepare TTE participants to be competitive applicants to four-year colleges. To date, approximately 86% of the students eligible to transfer to a 4-year institution were admitted and are now enrolled. This paper provides an overview of the TTE REU program, examples of the research projects, a description of the evaluation and assessment tools, and results of student transfer to 4-year institutions.

Introduction

In 2009 and again in 2011, the Obama Administration articulated its strategy to revitalize America in the document, "A Strategy for American Innovation: Securing Our Economic Growth and Prosperity" [1, 2]. The strategy calls for "Catalyz(ing) Breakthroughs for National Priorities" by "unleash(ing) a clean energy revolution" and "accelerat(ing) biotechnology, nanotechnology …". At the UC Berkeley, three NSF-funded centers, Center for Energy Efficient Electronics Science (E^3S), Center of Integrated Nanomechanical Systems (COINS), and Synthetic Biology Engineering Research Center (SynBERC), have been applying nanotechnology and biotechnology to address energy problems. E^3S is investigating transformative science and technology that reduce energy consumption in electronic devices by orders of magnitude. A major focus area for COINS is the development and integration of cutting-edge nanotechnologies into a versatile platform with various ultra-sensitive, ultra-selective, self-powered, mobile, wirelessly communicating detection applications, including energy conversion and sensing. SynBERC researchers are exploring the next generation of biofuels by using synthetic biology tools to engineer new microbes that can quickly and efficiently ferment complex sugars into competitively priced fuels. Together, these NSF-funded

Centers provide community college students research opportunities in the science and engineering fields of clean energy, nanotechnology, and biotechnology through UC Berkeley's Transfer-to-Excellence Research Experiences for Undergraduates (TTE REU) program.

In 2012, UC Berkeley received a three-year NSF REU Site award to fund the TTE REU program, a summer research program for community college students. With a focus on attracting a diverse body of community college students to science and engineering disciplines that are seeking solutions to the nation's energy problems, the TTE REU program objectives are to provide: research experience in high-caliber, cutting-edge research projects; advising to prepare students to transfer to competitive 4-year colleges/universities; enrichment activities to build students' confidence to continue in science and engineering; and exposure to the professional career opportunities that apply science and engineering training. Each year, the TTE REU Site hosts 15 community college students for a paid 9-week summer internship ($3,200 stipend paid in 2 installments, $1,600 during weeks 1 and 8), including a travel allowance of up to $350. Participants from diverse backgrounds, including low socioeconomic status (e.g., income, education), veterans, and underrepresented minority groups, are recruited from 110 community colleges in the California Community College System (CCCS). Specifically, the program targets students with majors in science and engineering, an interest in energy-related research, and who are ready for transfer to a baccalaureate program within one academic year after the completion of the TTE REU program.

Research Environment

TTE REU participants are matched with a UC Berkeley faculty member who is affiliated with E^3S, COINS, or SynBERC, and whose research focus is aligned with the participant's academic interests. The participant is paired with two research mentors, the faculty advisor and a graduate student mentor, who oversee and guide the student in independent research activities, through regular research group meetings and one-on-one discussions. The program provides engaging hands-on research experiences to further cultivate the student's interest in science and engineering careers. Below are three recent exemplary projects completed by community college students under the supervision of faculty mentors.

> Research area: Biofuels and synthetic biology
> Project title: Optimizing Plant-microbe Interactions for Sustainable Supply of Nitrogen for Bioenergy Crops
> Project description: Nitrogen (N) is an essential component of DNA and proteins. It is also a key element of life that is often limited in plants, which negatively affects their growth. In natural ecosystems, plants are strongly affected by their associated micro-biome. Plants have developed strong, symbiotic relationships with microbes to cope with the low availability of nitrogen in the soil. Optimizing the relationship between plants and diazotrophic bacteria (nitrogen-fixing bacteria) could provide adequate amounts of nitrogen to the host-plant and thus eliminate the need for fertilizer usage in energy crop cultivation. Therefore, we investigated the diversity of microbes in Tobacco (Nicotiana tabacum), considered as a potential energy crop for bioenergy production. Several bacterial isolates from the phylogenic order Rhizobiales were obtained from the rhizoplane and roots of this plant using several different N-deficient media. A majority of these isolates grew best with simple sugars and small organic acids. This investigation led

to the identification of isolates capable of fixing molecular nitrogen, as observed from polymerase chain reaction (PCR) amplification targeting the nifH gene. These results provide insight into the impact of plant associated microbes on the growth and survival of biofuel plants. This understanding is necessary for the development of eco-friendly, economically sustainable energy crops by decreasing their dependency on fertilizer.

Research area: Energy efficient electronics
Project title: Characterizing the Bilayer Tunnel Field-Effect Transistor
Project description: The bilayer tunneling field effect transistor (TFET) is a transistor which utilizes quantum tunneling as its switching mechanism. It is currently being investigated as a low-power alternative to the conventional transistor (MOSFET). The electrical properties of test devices are characterized utilizing a wafer probe station and semiconductor parameter analyzers. Through measurements of MOS capacitors, Schottky diodes, and P-N junctions, critical device properties, such as sheet resistance, contact resistivity, gate-oxide leakage current and breakdown voltage, and dopant concentrations, were determined. The results elucidated device operating voltage limits and off-state leakage current.

Research area: Nanotechnology
Project title: Light Induced Moving Molecule
Project description: As technology advances to enable further miniaturization of electronic device components, the need for techniques to manipulate matter at the nanoscale increases. For this reason, it is worthwhile to investigate molecules which possess optically sensitive mechanical properties that can be manipulated by light. Research has shown that the Monorotamer molecule can produce unidirectional rotational movement when illuminated by ultra-violet (UV) light. This project leverages this phenomenon to achieve light-induced movement of molecules, which potentially could be used in nano-scale machines. To characterize the behavior of Monorotamer, molecular samples were placed on a metal surface under a scanning tunneling microscope (STM) and UV light was applied for durations of 1 hour and 2 hours. STM images were taken before and after UV illumination to verify the displacement of the Monorotamer molecules. This procedure was repeated numerous times to make an accurate comparison of the molecular position before and after illumination.

Program Schedule

The TTE REU program provides a 9-week residential experience, wherein students spend the first week in a boot camp that introduces basic lab and research skills. During the first week, the students acclimate to the environment at a 4-year university and learn about the expectations for their research experience. Students participate in a research orientation that covers the following topics: safety training, strategies for reviewing technical journals and articles, maintaining your research notebook, scientific and research ethics, and data analysis and research results.

During the remaining 8 weeks, students work approximately 40 hours per week with their research mentors on their research project, rejoining the cohort of TTE REU participants for regular meetings on topics that provide them with more knowledge about science and engineering careers (e.g., science and engineering career panel; field trips to companies and

research centers; research seminars), help them prepare for transfer to a 4-year institution (e.g., meetings with department advisors and former community college students; seminars on scholarships, writing personal statements, and the transfer application process), and further develop their professional skills (e.g., seminars on writing scientific papers, giving technical presentations, and science communication). The TTE REU participants also spend time completing three program deliverables: personal statement, research poster, and research presentation.

Students participate in bi-weekly individualized advising sessions led by UC Berkeley's Transfer Alliance Project (TAP), a highly successful academic advising and enrichment program that prepares underserved community college students throughout California to be competitive transfer applicants to UC Berkeley and other four-year colleges. TAP counselors advise students on necessary steps to transfer to a 4-year institution and guide students through the process of planning their coursework for each semester/quarter they are at a community college. After completion of the TTE REU, the program continues to provide transfer advising to community college students for one academic year. This advising focuses on assisting the student with the process of applying to 4-year institutions.

Recruitment and Selection

Recruitment for the TTE REU program is two-fold, through online communications and in-person recruitment meetings. The online communications consist of the TTE REU website and recruitment e-mail messages sent to prospective students. The TTE REU program has a website (http://www.e3s-center.org/education/edu-tte-reu-appl2.htm) that is updated yearly to include program information, online application, project descriptions and mentors, and accomplishments of previous participants. In addition to the existing TTE REU program website, recruitment takes place through websites where students make general inquiries about summer research opportunities – including the "Undergraduate Research at UC Berkeley" website (http://research.berkeley.edu), NSF's REU website (http://www.nsf.gov/crssprgm/reu/list_result.cfm?unitid=10006), and the Pathways to Science website (http://www.pathwaystoscience.org/).

In addition to online communications, the program hosts in-person recruitment meetings. These meetings are critical due to the fact that some students find the prospect of conducting research at a top university like UC Berkeley to be intimidating. This can be especially true for a community college student, even if academically qualified. As a result, in order to ensure that qualified students do apply, in-person recruitment meetings augment typical online communication to emphasize the support structure provided in the TTE REU Site. During the fall and early winter, the TTE REU works with UC Berkeley's Transfer Alliance Project (TAP) and Mathematics Engineering Science Achievement (MESA) program to make presentations to students about the TTE REU program at additional California community colleges. The program also works with transfer center directors and faculty in STEM fields to distribute information and host in-person recruitment meetings with their students to explain the benefits of the TTE REU program.

The selection process is designed to ensure that accepted students are able to successfully complete the summer experience, will significantly benefit academically from conducting research, and are on track to transfer to a competitive 4-year college. The minimum requirements are:

- 3.25 GPA in science, engineering, or math
- Academically on target to transfer to a 4-year college after 1 more year at a community college
- Completed at least 2 calculus courses and at least 3 science courses in biology, chemistry, or physics, with at least one science course having a laboratory component. These courses must be on the list of University of California STEM major equivalent courses (www.assist.org).
- Will return to a community college in the fall upon completion of the REU
- U.S. citizen or permanent resident

By the application deadline, an applicant must also submit a complete application that comprises the following: transcript, statement of academic and career aspirations, statement of interest in the REU program with indication of the preferred research center, two letters of recommendations, and sample work. Incomplete and late applications are not accepted.

In selecting the cohort of TTE REU students, there is a three-phase selection process: pre-screening, center review, and selection oversight. During the pre-screening phase, community college students' transcripts are reviewed to determine the number of credits earned and the corresponding equivalent courses at UC Berkeley and to ensure that the minimum requirements are met. In phase two, qualified applications are reviewed by the applicant's preferred center. Each center, which has its own selection committee comprised of faculty, graduate students, and post-doctoral researchers, reviews and ranks the applications. Then the center concludes its review with a short list of candidates recommended for placement. The final phase, selection oversight, takes place when the TTE REU staff come together to review and approve the centers' selections.

Evaluation and Assessment

The TTE program has an evaluation plan that measures the success and efficacy of the REU Site. Evaluation for each cohort of TTE REU participants occurs in two stages: formative and summative. The formative evaluation, which is carried out to ensure the cohort is progressing as planned, includes a mid-term survey, weekly research journals, and one-on-one and work-in-progress 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 to achieve program and participant goals. Both the formative and summative evaluations 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.

In addition to the formative and summative assessments, the evaluation plan includes feedback from all program participants, including the community college students, faculty and graduate

student mentors, and program staff. The student evaluations include:

- Quality of faculty and graduate student mentor guidance during the research project
- Interest in research project
- Level of personal growth and confidence in methodological skills and technical knowledge
- Personal challenges faced during the program
- Insights gained for applying to a 4-year college/university and graduate school
- Knowledge of additional fields within science and engineering
- Knowledge of additional career options within science and engineering
- Interactions with program staff
- Continuation of research efforts after the completion of the TTE REU program
- Contribution to a scientific publication
- Information regarding future transfer and graduate school plans
- Overall satisfaction with the program
- Suggestions for improvement

Faculty and graduate student mentor evaluations include:

- Faculty and graduate mentor training and preparation
- Amount of time spent with student (hours/week)
- Level of preparation the student had at the start of the program
- Level of the student's growth in research skills, knowledge in pertinent area(s), and confidence/independence in conducting research
- Challenges student faced during the program
- Quality of student's final paper, presentation, and poster
- Continuation of research efforts after the completion of the program
- Contribution to a scientific publication
- Overall satisfaction with the program
- Suggestions for improvement

Project staff evaluations include:

- Progress and challenges student faced during the program
- Overall satisfaction with the program
- Suggestions for improvement

Conclusion

Participation in the TTE REU program provides community college students an intellectual experience, a sense of community with other like-minded community college students early in their science and engineering education, and continued transfer support and advising. All measures (self-reported and observed) indicate positive experiences for the students and mentors. A strong sense of community among the students and their mentors developed as well. Several students continued their research, and most of the students applied to a 4-year institution following the participation of the REU program. Approximately 86% (12 of 14) of the students

eligible to transfer to a 4-year institution were admitted to and are now enrolled in a 4-year institution. These students are currently pursuing their bachelor's degrees in a science or engineering field at UC Berkeley, UCLA, UC San Diego, or Columbia University.

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