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An NSF REU Site with Integrated Academia-Industry Research Experience – Four Years on the Road

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Program Overview

Most engineering students see industry or research career paths as binary. In their minds, a person can either focus on research (academic career) or design and management (industrial or professional career). This perception has a negative impact on the profession as it leads to missed opportunities to solve practical problems by applying new fundamental research, as well as basing fundamental research on current engineering problems.

Smart Structures Technologies (SST) is receiving considerable attention as the demands for high performance in structural systems increase. Although both the academic and professional engineering worlds are seeking ways to utilize SST, there is a significant gap between engineering science and engineering practice. To bridge the gap and facilitate the research infusion, San Francisco State University (SFSU) and the University of South Carolina (UofSC) collaborated with industry partners to establish a Research Experiences for Undergraduates (REU) Site program, which provides undergraduate students a unique opportunity to experience research in both academic and professional settings through cooperative research projects. The objectives of the program were to: 1) provide participants a unique and exciting summer research experience in both academic and industrial environments; 2) prepare students to become the catalysts to help close the gap between engineering science (academia) and engineering practice (industry); and 3) motivate the participants, especially those from underrepresented minority groups (URMs), not only to complete their undergraduate degrees but also to pursue advanced degrees and/or careers in engineering (Jiang *et al.*, 2018).

The program featured: formal training, workshops, and supplemental activities in the conduct of research; research experience through engagement in projects with scientific and practical merits in both academic and industrial environments; experience in conducting laboratory experiments; and opportunities to present the research outcomes to the broader community at professional settings. Populations from URMs are the main audience for this REU program.

Participants spent a total of 10 weeks in the program. In the first two weeks, participants were hosted at one of the academic institutions, SFSU or UofSC, receiving training for the upcoming research activities. During these two weeks, workshops, including professional development as well as subject-related preparation, were offered by one of the participating academic institutions. Students not at that institution virtually attended the sessions through videoconferencing. During weeks 3-9, the students spent part of their time at the academic institution and the rest with industry partners working on their research projects that were predefined by academic advisors together with industry mentors. Participants were back at the academic institution in week 10 to wrap up the program. Supplemental activities, including formal presentations by the students, roundtable discussions, technical tours, and cultural activities, were held throughout the program.

The three-year REU program was first implemented in the summer of 2018 and concluded in summer 2021, with a pause in 2020 caused by the COVID-19 pandemic. This paper describes the details of the program implementation in terms of recruitment, participant selection, partnership with industry, sustained mentorship, and its potential impact. The paper also describes findings from the program's external evaluator.

Recruitment

In fall 2013, community colleges enrolled 61% of Native American students, 57% of Hispanic students, and 52% of African American students (American Association of Community Colleges, 2015). In fact, almost three-fourths of all Latino students and two-thirds of all African American students who pursue higher education begin their postsecondary education in a community college (The Civil Rights Project, 2012). Particularly, the California Community College System is in a prime position to grow the future STEM workforce with its enrollment of approximately 2.3 million students (California Community Colleges Student Success Task Force, 2020). Twenty minority and primarily undergraduate institutions (15 of them are Hispanic-Serving Institutions, HSI) with limited science, technology, engineering, and mathematics (STEM) research capabilities were identified and committed to assisting the recruitment effort. Point-of-contacts at community and technical colleges were established as they play an increasingly important role in educating URMs. The recruitment plan included three recruitment mechanisms: 1) a project website; 2) personal emails and fliers to a targeted list of colleagues, and 3) advertisement on websites such as pathwaystoscience.org. A study was performed to evaluate the most efficient strategies for recruitment (Jiang *et al.*, 2019a). Results indicated that inviting participants through direct emails to colleagues was a particularly effective way of promoting the program. The program attracted a diverse and competitive pool of applicants and successfully selected cohorts of well-qualified participants. As shown in Table 1, the application numbers increased continuously, with 368 applicants in total. The number for 2021 in Table 1 combines the applications from 2020 and 2021, as the accepted candidates from 2020 were given priority if they chose to participate in the 2021 program. The applicant pool was diverse, with applicants from URMs (*URMs* in Table 1) consistently increasing from 44% in 2018 to 65% in the last year. On average, 41% of applications were from institutions with limited research opportunities (*Limited* in Table 1). Although they were not the targeted population in the original design of the program, the selection rubric was modified in 2020 to facilitate the recruitment of students from institutions with limited research opportunities. This change resulted in a cohort with 44% of participants from this group in the 2021 program.

Table 1. Applicant Pool and Accepted Participant Demographics

Demographics	2018				2019				2021			
	Applied		Participant		Applied		Participant		Applied		Participant	
	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%
Total	81	100%	8	100%	98	100%	8	100%	189	100%	9	100%
URMs	36	44%	6	75%	63	64%	5	63%	123	65%	8	89%
Limited	36	44%	0	0%	40	41%	1	13%	75	40%	4	44%

Participant Selection

While juniors were expected to have the necessary skills to benefit to the greatest extent from the REU experience, the program was also open to first- and second-year undergraduates. Our established partnership with the community colleges built the foundation for such recruitment, evident by the recruited one freshman and 11 sophomores (48%) out of the 25 participants in the REU program. The application package consisted of transcripts, statements of background and interests, and two letters of reference. Applicants were also asked about their preferred host institution and company profile, as matching participant expectations was recognized as a way to improve students' engagement with their research projects. By design, participants were paired to promote intersectionality (i.e., one from an institution with limited research opportunities and one from a research-intensive university). The intention was to promote peer learning, experience sharing from students with different university cultures, and observations through the intersectional lens (Hancock 2016). The applications were reviewed by a panel consisting of the project PIs and faculty advisors using a rubric considering the applicant's motivation, potential, school type, diversity, and preparation. Applicants with the highest scores were interviewed and the top-ranked candidates were recruited into the program. Participants' preferences for hosting institution, company type, and their skills would be considered when forming research groups. The program hosted 25 participants (8, 8, and 9 for 1st, 2nd, and last year of the program) where 19 (76%) were from URMs. Participating students from institutions with limited research opportunities increased from 0% in the first year to 44% in the last year.

Partnerships with Industry

One of the goals of this REU was to provide participants with a unique research experience in both academic and industry settings. Experiencing research in both worlds – the academic world where they learn about the value of guided research, and the professional world that is fast-paced and has less room for error –helped students transition from a relatively dependent status as undergraduates to an independent status as their competence and confidence increased. The collaborative research experience helped students establish professional networks, which are likely to be highly valuable for their professional development. This student-driven joint venture between academia and industry established a virtuous circle for knowledge exchange between the universities and industry partners, contributing to the advancement of fundamental research and implementation.

Participating students were paired up for each project. Each pair was guided by at least two mentors (one from academia and one from industry) and also had access to other experts for professional or technical advice. During weeks 3-9, participants split their time between the academic institution and the office of the partnering company, working on their research projects. The days with industry partners increased as the program progressed from one day (week 3) to two days (week 5) to facilitate the transition into the more independent industry environment. The PIs' prior connections with the industry were critical to identifying potential industry partners. All the participating industry partners had strong and established records in conducting research as well as in mentoring. Industry mentors who participated in an REU experience as students were particularly motivated and showed exceptional dedication and mentoring skills.

Sustained Mentorship and Potential Impact

Program activities allowed participants to expand their professional networks in both industry and academia. Even after leaving the program, many past participants have stayed in touch with their faculty/industry mentors for career advice, references, advice on application to the NSF GRFP, and internships. In addition, most of the students showed interest in continuing their research projects after the completion of the summer experience. One of the participants decided to continue the project as his senior design project. Two participants devoted time to work on the project for two semesters after the program ended. The outcomes from 2018 and 2019 (the 2021 cohort is currently developing their work for publication) resulted in 5 conference papers and 6 poster presentations at national conferences (Berger *et al.*, 2021; Donner *et al.*, 2019; Jiang *et al.*, 2018, 2019a,b,c, 2020; Meier *et al.*, 2019a,b; Ohstrom *et al.*, 2021). One of the 2018 REU participants was selected from a pool of almost 40 nominations to attend the 2019 NSF EEC Grantees Conference as an invited REU Site participant.

Each research project in the program is grounded in basic research with potential to be transferred to industrial applications. For example, the automated topology optimization platform developed by the 2018 cohort with ARUP has been used in actual design to reduce the carbon footprint by minimizing material usage. Through the collaborative nature of the program, participants have a greater appreciation of the benefits and challenges of academia-industry collaborations. As professionals, they could exploit these collaborations to bring new products and services to market, regardless of their choice of industry or academic career path.

Program Evaluation

The program evaluation was accomplished by EPRE Consulting LLC. Quantitative and qualitative analyses were used to evaluate if the project met its objectives. Continued self-assessment was performed based on feedback from participants, mentors, and the external evaluator. Improvements were implemented every year. For example, changes to the selection rubric were implemented to recruit more students from institutions with limited research opportunities. Paired student research groups were formed with one student from a research-intensive university and one from an institution with limited research opportunities. After adopting the modified strategy, students from institutions with limited research opportunities increased from 0% (2018) to 44% (2021). Several key findings from the external evaluator are listed below.

1. We wondered if industry experience would discourage students to continue on to graduate study. However, professional industry mentors with advanced degrees served as role models who motivated participants not only to complete their undergraduate degrees, but also to pursue advanced degrees and/or careers in engineering. As cited from the external evaluator's report, "The participants said that the REU experience had reinforced the importance of graduate study". This is also supported by the quantitative data - seven out of the ten participants (70%) who completed their undergraduate degrees went on to graduate school, while the other 3 are employed in engineering careers after obtaining their bachelor's degree.

2. The research experience provided by the program not only promoted and sustained the interest of REU participants in pursuing graduate education in STEM, but also provided them with the knowledge and tools to close the gap between academia and industry. As stated in the evaluation report, “The evidence indicates that the REU helped the students to deepen their understanding of research and to differentiate research in academic and industrial contexts.” and “By the end of the summer experience, the participants demonstrated mastery of the content they needed to successfully complete their projects and the professionalism and autonomy needed to work in a corporate setting.”

3. The program strengthened the collaboration between participating academic institutions and industry partners. As stated in our external reviewer’ report, “Both faculty and industry partners expressed high levels of satisfaction with the REU and interest in continuing to collaborate, both through the REU project, and in other possible projects, such as joint research, internships, and the like”. The partnership with the companies started with six local companies at the time the proposal was funded and expanded to 11 companies committed to the program by the beginning of summer 2021.

Concluding Remarks

In the past four years, we have been very fortunate to work with so many amazing students and dedicated faculty mentors and industry partners. We have gained very valuable experience and improved along the way of the journey. For future work, we are currently seeking the opportunity to continue to provide undergraduate students with a unique research experience in both academic and industry settings that promote an inclusive mindset and prepare them to be catalysts for industry-academia collaborations.

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