BOARD # 286: NSF REU: Multidisciplinary Collaborative Undergraduate Research Experience: Impacts on Engineering and Technology

Dr. Avimanyu Sahoo, The University of Alabama in Huntsville

Dr. Avimanyu Sahoo is an Assistant Professor in the Department of Electrical and Computer Engineering at the University of Alabama in Huntsville (UAH), Huntsville, AL. He earned his Ph.D. and Master's in Electrical Engineering from Missouri University of Science and Technology (previously known as University of Missouri), Rolla, MO, in 2015 and Indian Institute of Technology (BHU), Varanasi, India, in 2011, respectively.

His research group focuses on the convergence of Control Systems and Artificial Intelligence (AI) and its application in robotics and energy systems. More specifically, his group is researching in the area of event-based adaptive dynamic programming and reinforcement learning, optimal control of cyber-physical systems (CPS), intelligent control of robotic manipulators, smart battery management systems for lithium-ion batteries, and health diagnostics and prognostics of electric machinery. He has co-authored one book, three book chapters, and a total of 51 journal and conference publications in venues such as IEEE Transactions, Elsevier Journals, and flagship control conferences (IEEE CDC and ACC). His research is supported by the National Science Foundation (NSF), the Department of Energy (DOE), and the Department of Defence (DOD). He is currently serving as an Associate Editor in the IEEE Transactions on Neural Networks and Learning Systems and Frontiers in Control Engineering.

Dr. Sahoo has received several awards and honors, including the 2024 NSF EPSCoR Track IV Fellowship, the 2023-2024 Joseph C. Dowdle ECE Faculty Award at UAH, the 2020-2021 University Assessment and Testing Award and the 2021 Faculty Award for Leadership and Abiding Commitment to Diversity, Equity, Inclusion, and Awareness at Oklahoma State University. In addition to his eight years of teaching experience, he also possesses 11 years of industry experience.

Dr. Haejun Park, Oklahoma State University

Dr. Haejun Park is an associate professor in the Fire Protection and Safety Engineering Technology program at Oklahoma State University. His research interest lies in Fire Dynamics, Fire Modeling, Human Behaviors in fire conditions.

NSF REU: Multidisciplinary Collaborative Undergraduate Research Experience: Impacts on Engineering and Technology

1 Introduction

The holistic growth of an undergraduate student (UG) lies in exposure to an appropriate and valuable education, high-quality research that invigorates critical thinking, and activities that hone interpersonal skills early on [1]–[3]. National Science Foundation (NSF) sponsored Research Experience for Undergraduates (REU) program [4]–[8] is one such effort to inspire undergraduates to get involved in funded research activities during the summer. This not only encourages participation and retention in Science, Technology, Engineering, and Mathematics (STEM) majors but motivates these students to choose research as a future career [9]. There are ample research results available in the literature to support the above facts by studying and analyzing the outcomes of the REU programs nationwide [10]–[12]. One common similarity among these studies is that the cohort of students is either for engineering or engineering technology programs.

In contrast, this paper highlights the activities, outcomes, and impacts of a unique REU program that integrates engineering and engineering technology disciplines. The primary difference between engineering and engineering technology programs lies in their pedagogical approach. Engineering programs emphasize a fundamental, analytical approach, focusing on theoretical principles and mathematical modeling. In contrast, engineering technology programs adopt a more applied, hands-on approach, emphasizing practical implementation and real-world problem-solving. As a result, engineering technology courses are more application-oriented, and these programs are often referred to as applied engineering programs. Therefore, the REU program combines both fundamental and applied and cutting-edge research topics, including human safety, fire protection technology, mechanical engineering technology, electrical engineering, and artificial intelligence (AI). Engaging students from sophomore to senior levels, the program provided exposure to diverse research methodologies and multidisciplinary projects, fostering a comprehensive understanding of engineering systems and their real-world applications.

The first part of the paper details the program's structure, activities, and virtual collaborations between sites, followed by an analysis of its educational and research outcomes. It also presents formative and summative assessment results, showcasing the program's impact on student learning, skill development, and career trajectories. By examining these outcomes, we demonstrate how this collaborative research program has effectively prepared the next generation of independent researchers and engineering and technology leaders to tackle the challenges of an increasingly complex and interconnected world.

2 REU site research activities, methodology, and results

The REU program is executed collaboratively by the Engineering Technology (ET) department at Oklahoma State University (OSU) and the Department of Electrical and Computer Engineering (ECE) at UAH. Both departments provide a unique, multi-major research and learning environment for undergraduate and graduate students. Therefore, the primary objective was to build a cohort of undergraduate students from engineering and technology programs nationwide and involve them in hands-on fundamental research during the summer of 2024.

The overall research focuses on human safety in hazardous environments, especially investigating the fundamental and developmental challenges of human protection in hazardous work environments. Motivated by the common research focus that can enable a cohort experience for UG students, the collaborative REU site hosted nine UG students in the research activities for ten summer weeks. Five students joined the REU site at OSU and four at UAH. The faculty mentor team consists of nine researchers from both universities, along with 10 graduate students. The primary objectives of the collaborative REU site are to:

1) Provide multidisciplinary fundamental and applied research experience
2) Inculcate a research mindset to take the intellectual onus of research activities
3) Broaden participation by facilitating the involvement of students from women and underrepresented groups.
4) Provide the necessary impetus for graduate education and interpersonal skill development.

To achieve these objectives, in addition to individual research projects, the team hosted several professional development and social activities through our program. The details of these activites are presented in brief in the following paragraphs.

The REU cohort recruited nine students (5 at OSU and 4 at UAH) from diverse backgrounds, including women and underrepresented groups. The 10-week program comprised two phases: foundational research training and individual research activities. In the first week, students participated in lectures and lab-based training on LabVIEW for data measurement, ANSYS for modeling analysis, and 3D printing for manufacturing. Over the remaining nine weeks, they conducted independent research projects, supported by research and group meetings, as well as professional and social activities.

At OSU, the research projects include: (1) developing auxetic structures for pressure sensors in biomedical applications, (2) incident heat flux error comparison in one-dimensional plate thermometer modeling, (3) exploring robot manipulation and object deposition in safe locations with real-time human feedback, (4) safe human-robot interaction for smart personal protective equipment (SmaPP), and (5) a student-led survey on the willingness to wear non-medical masks, focusing on firefighter and emergency manager perceptions. At UAH, the projects were: (1) developing a lithium-ion battery charging and discharging system for SmaPP, (2) robotic hazard sensing, (3) federated split learning for human activity recognition with differential privacy, and (4) next-generation power electronics for SmaPP.

The undergraduates independently conducted all phases of research, including literature review, research design, implementation, and reporting, integrating both hands-on and theoretical analyses. Faculty mentors met weekly with students to monitor progress. Additionally, undergraduates worked alongside the graduate students, fostering a peer research environment for the undergraduates while providing a valuable mentoring experience for the graduate students. To foster collaboration, REU participants and mentors held biweekly Zoom meetings, where two students—one from each site—presented their work, encouraging questions and interaction among peers. This setup facilitated cross-disciplinary engagement, allowing engineering and engineering technology students to share insights and observe each other's approaches. The program also included various professional development and social activities. At UAH, students participated in weekly professional development sessions every Thursday led by experts from multiple departments. Key topics covered were research ethics, open inquiry, viewpoint diversity and constructive disagreement, intellectual property, copyright and patents,

poster preparation, graduate school, and prestigious scholarships & fellowships, and effectively talking about research. Based on the student interest, we plan to extend this training for OSU through virtual meetings in the following years.

Of the nine students, six successfully completed their projects. All students presented their work on the program's final day, with participants from both sites attending the presentations. Each student also prepared and submitted a final project report. Two students' work led to conference papers: one on federated learning for human activity recognition, which was accepted for a poster presentation, and another on willingness to wear non-medical masks, which is planned for submission to the ASEE conference. An external evaluator evaluated the REU activities at both sites, presented in detail next.

3 Evaluations and results

In this section, the REU site external evaluation results are discussed. The results were notified to the PIs of the collaborative REU site, maintaining the anonymity of the survey responses. The survey provided a qualitative analysis of the 10-week REU program, focusing on four key areas: (A) participant characteristics, including technical skills, prior research experience, attitudes and beliefs about research, and confidence levels; (B) research mentors' evaluations of the participants; (C) the program's impact on the participants; and (D) participant feedback on the program. The results for each category, based on student responses, are presented below.

A. Participant characteristics

In the following, the strengths, attitude toward research, and research competitiveness at the beginning of the REU program and after the program are evaluated and presented briefly.

1) *Technical skills and prior research experience*. The nine participants had diverse technical skills and research experience. Five had prior research experience, while four did not. Most expressed strong interest in engineering and technology, particularly robotics and computer science. Skills ranged from basic programming to advanced expertise in machine learning, robotics, and CAD. Three participants had proficiency in multiple programming languages, four had moderate experience with one language, and two had minimal or no programming knowledge.
2) *Attitudes and Beliefs*. At the start of the program, all participants held positive views on research, its societal value, and its role in driving innovation and addressing global challenges. While most showed interest in engineering or technology careers, five expressed a preference for research over-engineering practice, citing personal interest, potential impact, and opportunities for innovation. Some participants noted concerns about the time commitment and technical demands of a research career.
3) *Confidence levels.* Participants' confidence in succeeding in research and engineering varied. Three expressed high confidence with a clear sense of direction, four showed moderate confidence with a willingness to learn, and two had lower confidence, feeling uncertain about their skills and career paths.

B. Mentor evaluation on the student participants.

Eight faculty mentors evaluated participant performance, offering insights into strengths and areas for improvement. Highly engaged and motivated students received positive feedback, while those with limited technical skills faced challenges. One mentor praised a participant's enthusiasm and influence on the group, stating, "They were eager to learn and take on

challenges, positively impacting others." Conversely, another noted, "Difficulty with programming concepts hindered their project progress." These evaluations highlight the importance of engagement and skill development for success.

C. The impact of the program on the student participants

The program had a significant impact on participants' attitudes, beliefs, and skills. Many reported increased confidence in their research abilities and a deeper understanding of the research process. The hands-on experience and mentorship provided by the program were particularly valuable in fostering these positive outcomes.

TABLE I
THE NUMBER OF PARTICIPANTS INDICATING THE CHANGE OF CONFIDENCE LEVEL.

Level of confidence	**Pre-program**	**Post-program**
High	3	5
Medium	4	2
Low	2	–

- *Increased confidence in research abilities.* All participants agreed or strongly agreed that the program boosted their confidence in their research abilities, attributing this growth to hands-on experience, mentorship, and opportunities to apply their knowledge. As shown in Table I, even participants with initially low confidence reported significant improvement in self-efficacy.
- *Enhanced technical skills.* All participants reported gaining new technical skills and improving existing ones, with eight noting significant progress and one reporting moderate improvement. They highlighted learning tools like MATLAB and ANSYS and valued the hands-on lab experience.
- *Positive career outlook.* Eight participants reported increased interest in research careers, while one noted no change. They credited the program with clarifying career goals, providing insights into the research process, and emphasizing the value of mentorship and networking opportunities.
- *Improved understanding of the research process.* All participants agreed or strongly agreed that the program enhanced their understanding of the research process. They gained a deeper appreciation for its complexities, reflected on challenges encountered, and shared the strategies they used to overcome them.

D. The program feedback from the student participants

Seven participants reported positive experiences, praising the program's hands-on research, mentorship, and collaboration. Two highlighted concerns about limited personal support and structure. One noted the need for a dedicated mentor, and another suggested more guidance and training. Participants valued their experiences, with 100% willing to participate again and recommend the program. As one shared, "I made lifelong friends, received outstanding mentor advice, and improved my approach to scientific concepts." Another remarked, "I would absolutely participate again; it was exciting to study topics I'm passionate about in a new environment." The program's impact was reflected in the skills gained and the participants' enthusiasm to promote it.

The hands-on research experience, mentorship, and opportunities for collaboration made the program most enjoyable. Conversely, participants found limited social activities, a lack of structure, and time constraints to be the least enjoyable. Suggestions for improvement included

setting clearer project expectations, providing increased mentorship and structured learning opportunities, and enhancing communication between participants and mentors.

4 Conclusions

This paper outlines the structure and outcomes of a collaborative REU program between OSU and the Department of Electrical and Computer Engineering at the University of Alabama in Huntsville, Alabama. The program demonstrated significant success in meeting its objectives, fostering participant confidence, technical skills, and research proficiency while positively shaping career aspirations. Participants reported notable gains in programming, data analysis, and software utilization, along with a deeper understanding of the research process, including problem identification, investigation, and dissemination of findings. These outcomes highlight the program's effectiveness in equipping students with essential skills and insights for research and professional development. The positive outcomes to date underscore the program's potential to contribute meaningfully to the development of future scientists and engineers, preparing them to tackle complex challenges and advance innovation in their fields. While the program has shown great promise, there are opportunities for improvement. Addressing areas such as clearer program structure, enhanced mentorship, and improved communication among participants, mentors, and staff can further elevate its impact. By incorporating these refinements, the program can become an even more enriching and transformative resource for aspiring researchers.

Acknowledgment

The authors acknowledge the NSF Engineering Workforce Development program and NSF EPSCoR for jointly funding the collaborative REU project (award # 2244293 and # 2244294).

References

[1] A. R. Bielefeldt, "Student learning outcomes from an environmental engineering summer research program," in *2012 ASEE Annual Conference & Exposition*, 2012, pp. 25–1186.

[2] C. M. Kardash, "Evaluation of undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors." *Journal of educational psychology*, vol. 92, no. 1, p. 191, 2000.

[3] H. Sheng, R. G. Landers, F. Liu, and T. Nguyen, "A longitudinal study on the effectiveness of the research experience for undergraduates (reu) program at missouri university of science and technology," in *2014 ASEE Annual Conference & Exposition*, 2014, pp. 24–63.

[4] National Science Foundation, "Research experiences for undergraduates (reu)," 2025, accessed: 2025-01-13. [Online]. Available: https://new.nsf.gov/funding/initiatives/reu

[5] P. R. DeLucia, A. L. Woods, J.-H. Kim, N. Nguyen, E. W. Wang, and J. Yang, "Learning to become researchers: Lessons learned from a research experience for undergraduates (reu) program focused on research in the psychological sciences with real-world implications," *Scholarship and Practice of Undergraduate Research*, vol. 4, no. 4, pp. 10–22, 2021.

[6] P. Ann Mabrouk and M. Gapud Remijan, "Critical traits of graduate student mentors affecting students' science identity development in an nsf-funded research experiences for undergraduates (reu) program," *Mentoring & Tutoring: Partnership in Learning*, vol. 31, no. 1, pp. 103–121, 2023.

[7] T. Sulbaran, "Research experience for undergraduates (reu) on construction decision-making," in *2023 IEEE Frontiers in Education Conference (FIE)*. IEEE, 2023, pp. 1–5.

[8] R. Burcin and J. M. Dolan, "Transforming undergraduate research experiences with experiential learning," 2023.

[9] M. Mastronardi, M. Borrego, N. Choe, and R. Hartman, "The impact of undergraduate research experiences on participants' career decisions," *Journal of STEM Education: Innovations and Research*, vol. 22, no. 2, pp. 75–82, 2021.

[10] D. Lopatto, "Undergraduate research experiences support science career decisions and active learning," *CBE—Life Sciences Education*, vol. 6, no. 4, pp. 297–306, 2007.

[11] E. Seymour, A.-B. Hunter, S. L. Laursen, and T. DeAntoni, "Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study," *Science education*, vol. 88, no. 4, pp. 493–534, 2004.

[12] A. L. Zydney, J. S. Bennett, A. Shahid, and K. W. Bauer, "Impact of undergraduate research experience in engineering," *Journal of Engineering Education*, vol. 91, no. 2, pp. 151–157, 2002.