REU: Enhance REU Participants' Identification with Research Training and Engagement

Objective and Motivation

Since the National Science Foundation (NSF) established the Undergraduate Research Participation Program in 1958, thousands of Research Experiences for Undergraduates (REU) sites have been supported by various agencies, including the NSF, the National Institutes of Health, the Department of Energy, and the Department of Education [1, 2]. The REU program has proven to be an effective means of fostering students' research interests, encouraging them to pursue advanced degrees in science, technology, engineering, and mathematics (STEM) fields, and cultivating a diverse and skilled workforce for STEM careers [3, 4].

A strong STEM identity has been linked to a higher likelihood of pursuing a STEM-related career. Understanding how these identities develop and are nurtured—both through formal institutional education and informal programs like the REU—is critical. Previous research has highlighted two key factors in STEM identity formation: (1) an individual's sense of belonging to an educational institution and to the STEM fields [5, 6]; and (2) authentic learning experiences and outcomes [7-9]. These factors are inherently integrated into the activities offered through REU programs. Therefore, this study aims to evaluate the impact of REU training experiences on participants' STEM identities and their subsequent career paths.

Methods

A total of 38 undergraduate students were recruited and trained in robotics for 10 weeks with the support of an NSF REU site at the University of Texas at San Antonio (UTSA) during 2021-2024. REU activities were organized to provide technical and soft skills for REU participants' career development and to enhance their belongings at the REU site and professional societies.

Authentic learning experiences

REU project training: Faculty members and graduate research assistants (GRAs) developed short courses and seminars to train REU participants for their selected research projects during the first two weeks. Each lecture was followed by a hands-on session for REU participants to apply their knowledge and skills. REU participants were expected to identify specific tasks with their mentor and define the project outcomes and research plan by the end of the second week.

Project development: REU participants focused on hands-on research projects from the third to the ninth week. Faculty members were requested to spend 4 hours/week helping REU participants formulate their problems, verify their ideas with simple examples, and validate their algorithms. GRAs were also assigned to help REU students with computer simulation, experimental equipment setup, and other laboratory operations.

Project management: From the third to the tenth weeks, weekly meetings were scheduled between REU participants and their mentors to discuss the research progress. A spirit of teamwork was encouraged among the REU participants who were working on related projects. Program meetings of all faculty members and REU participants were held during the fourth and seventh weeks. REU participants presented their independent research results and status reports during the program meetings.

REU participants were encouraged to exchange ideas with each other and mentors in program meetings, brown bag lunch meetings, and research seminars organized by the REU site. REU participants also practiced the research, problem-solving, presentation, and communication skills they had acquired in program meetings. Such meetings and interactions among REU participants provided an opportunity to enhance their sense of belonging to the REU site.

Enhancing REU participants' belonging to the REU Site

Student-Organized and Student-Run Annual REU Conference and Social Events: At the end of the 10th week of each year, each REU student was required to submit a final project report. A student-organized and student-run annual REU conference was held for REU students to present their research findings. Presentations from REU participants were recorded and broadcasted on YouTube and deposited in the UTSA library for public citations.

Project Outreach: After leaving the REU sites, REU participants broadened the outreach of their research. The effort included (1) pursuing publications of the research in the following academic years to disseminate their research findings; (2) publishing pedagogic manuscripts on enhancing research experience for undergraduates [2, 4, 10, 11]; (3) establishing and maintaining a student pipeline from high school, college, to graduate school to expand the outreach of the program and make the REU site more competitive in recruiting exceptional students [12, 13]. The student pipeline was established by 1) inviting local high school students to visit REU labs, 2) demonstrating REU participants' research results at local science fairs to attract more high school students to study science and engineering, and 3) encouraging our REU participants to join graduate schools. Some REU alumni became our teaching and research assistants after joining the graduate school at UTSA. This student pipeline provided early exposure to research activities for high school students and helped ensure the continuity of our research program.

Interactions among REU participants and mentors: We have established email lists and social media groups to foster a collaborative environment for REU participants, utilizing platforms such as LinkedIn and Discord. REU mentors communicate with participants regularly checking their academic progress and professional development following their REU training.

Enhancing REU participants' belonging to the professional community with learn-practice-service cycle

In the current REU program, we implemented a learn-practice-service cycle to enhance participants' STEM identity. REU participants acquired essential skills and knowledge, which they applied to hands-on project development. Additionally, we encouraged them to use their expertise to address the challenges of our society. To highlight the significance of their research

projects, we created online videos, invited speakers from academia and industry, and organized field trips to local industries where participants could observe real-world applications of their research. These activities helped participants identify specific research topics and refine their research directions to address societal needs.

We also integrated service-learning by encouraging REU participants to mentor local middle and high school students. This mentoring involved answering questions, demonstrating project results, teaching elementary and middle school students to assemble and control robots, and inspiring them to pursue engineering studies. These activities motivated the younger students and deepened the REU participants' understanding of their research. The service-learning component extended beyond the summer REU programs. We invited REU alumni to return and present their research findings to the new cohorts, serve as judges for the FIRST Robotics Competition, act as evaluators for the annual REU conference, and volunteer at IEEE conferences. These experiences fostered their professional growth, broadened their perspectives, and inspired them to set ambitious career goals while they met more professionals through their service.

By engaging with K-12 students and professional organizations, our REU program provided participants with valuable opportunities to contribute to society, enhance their independent thinking about research, and sustain their interest in STEM fields even after completing the program. Moreover, our REU participants served as role models for other undergraduates, showcasing their research achievements, strong technical skills, and professional experiences.

Post-REU surveys were administered annually at the conclusion of the program. The survey included questions related to REU participants' sense of belonging, career choices, interactions with their mentors during and after the training, and work attitude.

Results

A total of thirty-eight REU participants were recruited from 16 colleges, the locations of which are shown in Figure 1. REU participants from 13 institutions had little or no access to research before joining the REU site.

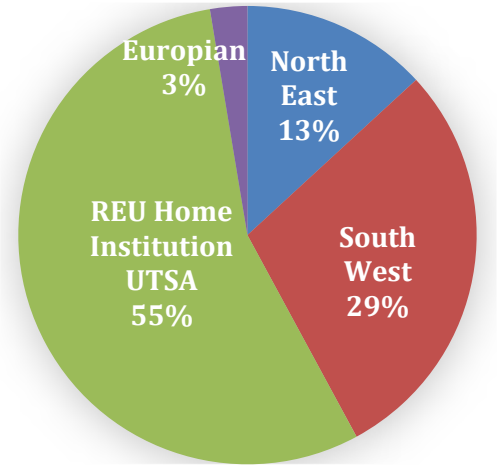

Figure 1. Locations of institutes of 38 REU trainees in an REU program from 2021-2024.

Results from post-REU Survey

The post-REU survey was administered in the 10th week before the REU participants left the site. A total of 35 responses were collected. The survey included questions focusing on four areas: 1) the knowledge and skills gained by the REU participants and the self-evaluation of their efforts; 2) the impact of the REU program on participants' career choices; 3) the engagement of REU participants with

their mentors and other participants; and 4) suggestions and comments on REU activities and management. Responses to a sample question in Part II are listed in Table 1.

Table 1. Response to sample questions in the post-REU survey related to belonging.

Survey Question: As a result of your research experience, to what degree have you made gains in the following areas:	Little Gain	Good Gain	Great Gain
Networking, meeting new people, importance of mentors		14.29%	85.71%
Increased confidence and other personal gains		17.14%	82.86%
Clarified plan for future		20.00%	80.00%

All responses in the survey indicated that they would continue to major in STEM at a four-year college or university. In addition, more than 70% of REU participants expressed their interest in continuing to graduate school in a STEM major, a clear marker for their STEM identity. Over 80% of 35 REU students responded positively to the research skills they gained in the REU training. Over 90% of REU trainees responded positively to the PI's availability during the REU training and the support provided for their research.

Outcomes of the REU Site

The research findings from REU participants resulted in 29 posters/oral presentations at international conferences, 20 conference proceedings, and 14 journal manuscripts. A total of 12 REU trainees joined graduate schools after REU training and continued working with their REU mentors on publications such as abstracts, conference proceedings, or journal papers. Our results illustrate that interactions among trainees and faculty mentors sustain the trainees' interest in their trained areas for a future career and significantly enhance their STEM identity. Since most of our trainees are still in their undergraduate programs, we expect more REU trainees to join graduate schools in the future.

Conclusion

Responses from post-REU surveys and the outcomes of REU training confirmed the critical role played by authentic learning experiences and a sense of belonging in shaping STEM identity. Our findings provide valuable insights into designing REU activities that effectively strengthen the STEM identity of REU participants.

Acknowledgement

This material is based upon work supported by the NSF under Award No 2051113, 1736209, and 2007718.

References

[1] National Science Foundation Division of Undergraduate Science Mathematics Education, *Report on the National Science Foundation Disciplinary Workshops on Undergraduate Education: Recommendations of the Disciplinary Taskforces Concerning Critical Issues*

in US Undergraduate Education in the Sciences, Mathematics and Engineering (no. 3). National Science Foundation, 1989.

[2] Y. Jia, T. Wang, C. Chen, and Y.-F. Jin, "Board 410: Tracing the Evolution of NSF REU Research Priorities and Trends," in *2024 ASEE Annual Conference & Exposition*, 2024.

[3] L. Martin-Hansen, "Examining ways to meaningfully support students in STEM," *International Journal of STEM Education,* vol. 5, no. 1, p. 53, 2018.

[4] Y. Jin, C. Qian, and S. Ahmed, "Closing the Loop: A 10-year Follow-up Survey for Evaluation of an NSF REU Site," in *ASEE Annual Conference and Exposition*, Minneapolis, MN., 2022. [Online]. Available: https://peer.asee.org/41048. [Online]. Available: https://peer.asee.org/41048

[5] D. R. Johnson *et al.*, "Examining sense of belonging among first-year undergraduates from different racial/ethnic groups," *Journal of College Student Development,* vol. 48, no. 5, pp. 525-542, 2007.

[6] K. I. Maton *et al.*, "Outcomes and Processes in the Meyerhoff Scholars Program: STEM PhD Completion, Sense of Community, Perceived Program Benefit, Science Identity, and Research Self-Efficacy," *CBE—Life Sciences Education,* vol. 15, no. 3, p. ar48, 2016, doi: 10.1187/cbe.16-01-0062.

[7] M. E. Beier, M. H. Kim, A. Saterbak, V. Leautaud, S. Bishnoi, and J. M. Gilberto, "The effect of authentic project-based learning on attitudes and career aspirations in STEM," *Journal of Research in Science Teaching,* vol. 56, no. 1, pp. 3-23, 2019.

[8] D. Wallace and A. Bodzin, "Developing scientific citizenship identity using mobile learning and authentic practice," *The Electronic Journal for Research in Science & Mathematics Education,* vol. 21, no. 6, 2017.

[9] A. Singer, G. Montgomery, and S. Schmoll, "How to foster the formation of STEM identity: studying diversity in an authentic learning environment," *International Journal of STEM Education,* vol. 7, pp. 1-12, 2020.

[10] Y. Jin, R. Applonie, P. E. Morton, M. C. Conkel, T. K. Nguyen, and C. Qian, "Quantification of Competencies-based Curricula for Artificial Intelligence," in *2023 ASEE Annual Conference & Exposition*, 2023.

[11] R. Schroeder, J. Niu, A. Malshe, S. Hum, S. Flemming, and I. Thacker, "Enabling Widespread Engagement in DS and AI: The Generation AI Curriculum Initiative for Community Colleges," in *Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 2*, 2024, pp. 1938-1938.

[12] J. C. Lu, V. Liu, J. Jin, P. Olkowski, and Y.-F. Jin, "Cultivating Robotic Professionals: A Learning-Practice-Service Educational Framework," in *2024 ASEE Annual Conference & Exposition*, June 23, 2024, doi: 10.18260/1-2--47098. [Online]. Available: https://peer.asee.org/47098

[13] J. Jin *et al.*, "Eight-Year Journey with the FIRST Program: How Robots Build Kids," in *2024 ASEE Annual Conference & Exposition*, June 23, 2024, doi: 10.18260/1-2--47228. [Online]. Available: https://peer.asee.org/47228