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Closing the Loop: A 10-year Follow-up Survey for Evaluation of an NSF REU Site

Yufang Jin (Professor)

Dr. Jin is a full professor with the Department of Electrical and Computer Engineering at the University of Texas at San Antonio. Her research interest focuses on modeling and control of nonlinear systems, applications of deep learning algorithms to biological systems, and pedagogy in Engineering Education.

Chunjiang Qian (Assistant Professor)

Dr. Chunjiang Qian received his Ph.D. degree in Electrical Engineering from Case Western Reserve University, 2001. Since August 2001, he has been with the Department of Electrical and Computer Engineering, University of Texas at San Antonio, where he is currently the department chair and Mary Lou Clarke Endowed Professor. His current research interests include robust and adaptive control, nonlinear system theory, optimal control, network control, and mathematical foundation of deep learning. He has also applied research to UAV systems, power generation systems, electric vehicles, and marine vehicles. Dr. Qian is a recipient of 2003 U.S. National Science Foundation (NSF) CAREER Award and one of the inaugural recipients of the University of Texas System Regents' Outstanding Teaching Award in 2009. He received the 3rd Best Paper Award in the ISA (International Society of Automation) Power Industry Division Symposium (2011) and the Best Poster Paper Award in the 3rd IFAC International Conference on Intelligent Control and Automation Science (2013). He currently serves as an Associate Editor for Automatica and International Journal of Robust and Nonlinear Control. Dr. Qian is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE).

Sara Ahmed (Assistant Professor)

Dr. Sara Ahmed is an Assistant Professor in the Electrical & Computer Engineering Department in the University of Texas at San Antonio. She received her Bachelor's, Master's and Ph.D. degrees all in Electrical Engineering with a Power Electronics concentration from Virginia Tech, Center for Power Electronics in 2006, 2007, and 2011 respectively. Dr. Ahmed has five years of prior R&D industry experience as a Senior Scientist at ABB's U.S Corporate Research Center in Raleigh, NC. Her primary research interests are in the area of modeling, simulation and analysis of power electronics systems with a focus on control, stability, fault analysis, model prediction, integration of renewables and hardware-in-the-loop modeling and testing. She holds eight granted U.S. patents, 2 U.S. patent applications and more than 45 referred publications.

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ABSTRACT

Objective and Motivation: Research Experience for Undergraduates (REU) has been a very effective way to foster students' interest in research, attract more students to pursue advanced degrees in Science, Technology, Engineering, and Mathematics (STEM), and promote a well-trained diverse workforce in the future. Most evaluations of REU programs focus on current progress and outcomes in a near future. However, most REU trainees are juniors and the post-graduate education programs for advanced degrees, especially Ph.D. training, can easily span from 3 to 5 years, leading to a much longer period than the funding period of REU programs. With this consideration, the final report on REU programs can not include the complete outcomes of REU programs. The goal of this project is to establish a closed-loop evaluation structure for identifying significant factors to promote undergraduate students in the engineering career path, and integrating the experiences learned from the previous REU program into an ongoing REU program.

Methods: We executed a survey for 26 former REU trainees who were trained 10 years ago. Questions in the survey for former REU trainees include when and where they earned their highest academic degree, GPA at graduation, a career path in academic or industrial sectors, careers in STEM or not, regions of current locations, trainees-advisor interactions using email/social media, and REU trainees' follow-up evaluation of the REU site. Among all 26 former REU trainees, 11 got a master's degree or doctoral degree in either Computer Science or Electrical and Computer Engineering. Further, 3 out of 7 trainees who got Ph.D. degrees chose an academic career path in their trained research areas.

Assessment Methods: REU trainees' demographics, first-generation student or not, career achievement, and evaluations of the REU site were analyzed by an evaluation model associated with their final degree outcomes, academic GPA, number of publications during the REU training, and frequency of interactions among faculty members and the REU trainees during and post the REU training.

Statement of Results: This is the first longitudinal study on an assessment of the benefits of REU in Electrical and Computer Engineering. This study provides insight into the role of research experiences prior to graduate school in the transition of REU trainees into their professional career development. The findings strongly support that engagement of REU trainees provides thrust in their transition to graduate schools. Specifically, joint publications, interaction strength with their REU mentors post-REU training, and professional community activities are the top three contributing factors to the engagement.

Objective and Motivation

Research Experience for Undergraduates (REU) has been a very effective way to foster students' interest in research, attract more students to pursue advanced degrees in STEM-related fields, and promote a well-trained diverse workforce in STEM-related career path [1-3]. The impacts and benefits of REU have been confirmed by several large-scale surveys [1-7]. It's reported in a study by Linn in 2015 that about half of the 60 empirical studies published during 2009-2015 exclusively draw conclusions from self-report surveys or interviews [4]. In the surveys, most questions for future career development are opinion or intention related not facts related due to the different time spans of REU programs and the training process for REU trainees to pursue advanced degrees. Most REU trainees are juniors, and it will take 2-3 years for the trainees to finish their bachelor's degrees. The following post-graduate education programs for advanced degrees, especially Ph.D. training, can easily span from 3 to 5 years, leading to a much longer training period than a typical 3-year (or 4-year) funding period of REU programs. This difference also leads to a lack of facts on training outcomes in the annual assessment report and final reports which focus on evaluating current progress and outcomes in the near future of REU programs.

Very few efforts have been dedicated to examining the ***longitudinal*** effects of REU participants on their final career choices and degrees earned. To bridge the gap, a 10-year follow-up post-REU survey was conducted to examine the outcomes of a National Science Foundation (NSF) REU program performed from 2007 to 2010 at the University of Texas at San Antonio (UTSA). A group of 26 REU trainees was contacted for the major and time for their final degree earned, their career choices, their post-REU engagement with the REU site, and the impacts of REU training on their career choices. The goal of this project is to establish a closed-loop evaluation structure for identifying significant factors to promote undergraduate students in the engineering career path, and integrating the experiences learned from the previous REU program into an ongoing REU program.

Background

The disparity in College STEM Education

During the past 20 years, the number of college graduates with bachelor's degrees increased by about 60% from 1.24 million in 2001 to 1.98 million in 2018 [8]. Similar trends of increase were also observed for Master's (74%) and doctoral degrees (50%) [9]. The recent statistic in the United States also indicates a shift in the popularity of STEM majors with the largest number of graduates as of 730,394, accounting for 18.3% of college graduates. Further, about 12.9%, 59.2%, 23%, and 4.9% of STEM graduates earn Associate's, Bachelor's, Master's, and doctoral degrees, respectively [8].

Together with the increase in the number of college graduates, the demographics of the college graduates raise concerns about the disparity among ethnicity and sex groups. The percentages of college graduates are significantly different for American Indian/Alaska natives (0.6%), Asian and pacific islanders (6.6%), African American (11.1%), Hispanic (13.1%), Caucasian (59.1%),

two or more races (2.9%), and non-resident (6.7%), respectively. Such difference was enlarged in Engineering considering the population of each ethnic group in the United States. African American and Hispanic students are substantially underrepresented in the engineering area. Currently, the overall Hispanic and African American population accounts for 30% of the national population in the U.S. while 14.6% of engineering bachelor's degrees were conferred to Hispanic and African American students compared to 60.8% to Caucasians [10, 11]. Further, about 78% of graduates in engineering are male.

Post-Graduate Education in Engineering for Underrepresented Groups

Recent NSF data showed that only 21% of science and engineering bachelor's degrees were earned by underrepresented minorities in 2016. That number continues to decrease at the master's level (13%) and doctoral level (9%) [12]. Post-graduate education for underrepresented students in engineering fields faces much more severe challenges. Hispanics and African Americans earn even lower proportions, 6.1% and 4.7% of engineering master's and doctoral degrees, respectively, which is much lower than their population percentile [10, 11]. With the prediction that the Hispanic and African American population will reach 45% of the population in the United States in the year 2045, there is a thrust to attract more Hispanic and African American students to the engineering fields and well prepare them to enter the job market [12, 13].

Besides this long-term impact, the low educational ratio of Hispanics and African Americans has partially contributed to the underrepresentation of the Hispanic and African American population in high-skill high-pay occupations. Training underrepresented students with high skills in engineering will create more opportunities for underrepresented minorities in highly paid engineering careers. This effort may help reduce the Hispanics' poverty rate (18.3%), which is significantly higher than the 12.3% of the general population in the United States [14, 15].

Social Economic Impact of REU programs

NSF in the United States stated that "it is clear that the academic scientific community regards the involvement of undergraduate student majors in meaningful research and related scholarly activity with faculty members as one of the most powerful instructional tools" [7]. After that, hundreds of REU sites have been supported each year by different agencies including NSF, National Institute of Health, National Aeronautics and Space Administration, Department of Energy, Department of Defense, and Department of Education. In addition to the federal support, many institutes and private foundations have allocated resources to support undergraduates' research experiences. These efforts have led to a 70% increase in undergraduate STEM research participation in 2001 compared to the previous decade [16] and the number of participants continuously increases every year [17, 18]. Previous studies have shown significant impacts of REU on fostering undergraduates' interest in the STEM fields [1, 5-7], improving workforce diversity [19], encouraging enrollment in graduate schools [1], and enhancing educational outcomes [5, 20]. However, most existing studies focus on recent REU participants and there is a lack of research on the impacts of REU programs from a longitudinal perspective.

Mentor's Critical Role in REU Programs

REU programs request a significant amount of time, funding, and effort from both REU trainees and mentors. Faculty involvement has played a critical role not only by providing research guidance in the lab but also by faculty-student interactions to enhance student engagement [21, 22]. Research supports the idea that mentoring is a crucial component of students' REU experiences. Previous studies reported a correlation between students' overall evaluations of their REU programs and their ratings of their mentors [2]. It's also reported that effective guidance from the mentor and interactions between mentors and REU trainees might be critical in students' decisions in future career choices [1, 3]. Most studies suggested that mentors should give project ownership to the REU trainees, involve REU trainees in the research process, guide the REU trainees from dependency to independency in research, and establish an environment for open and honest communication, collaboration, and peer-tutoring [1, 3, 6, 22]. Though several large-scale surveys were conducted, the surveys focused on recent trainees with their intention to go STEM careers and post-graduate degrees. No actual data on career and final degree earned has been reported.

Therefore, the primary objective of this research is to form a close-loop evaluation structure for an REU program with a 10-year post-REU training survey. We collected the final career choices and degrees earned from a cohort of 26 REU participants who were trained by a 10-week summer NSF REU program in a minority-serving institute during 2007-2010. The secondary objective is to illuminate the relationship among their career choices, demographics, and engagement with the REU site, and integrate the findings into the mentorship in an ongoing REU site at UTSA.

Methods

REU Trainees

A total of 26 NSF REU participants were reached through email, phone, and LinkedIn group during 2019-2021. A total of 20 REU trainees (77%) responded to the survey. For the 6 trainees who did not respond, we confirmed their acquisition of a bachelor's degree with the point of contact at their institute and verified their career with their LinkedIn profiles.

10-year Follow-up Survey Design

The 10-year follow-up survey includes 7 fact-based questions and 1 opinion-based question listed as follows.

1. Which year did you join the REU program?
2. Are you attending any graduate school now?
3. What's your highest academic degree by now?
4. If you have an MS or Ph.D. degree, which university and field of study did you get your degree?
5. Which company or institute are you working with now?
6. Did you contact your REU fellows right after REU training?
7. Do you still contact your REU fellows now?
8. Does your REU experience have a significant impact on your career choice?

Engagement Measurement

The engagement of REU trainees with the REU site was quantified based on binary (yes /no) questions focusing on the interaction frequency, collaboration strength among REU trainees and REU mentors, and involvement in the professional communities.

1) Did the REU trainee contact the REU mentors for reference letters or recommendations within 2 years post-REU training?
2) Did the REU trainees contact the REU mentors for any reason post-REU training?
3) Did the REU trainees come to the home institute REU site for graduate school?
4) Was the REU trainee an undergraduate student at the REU home institute?
5) Did the REU trainees respond to emails from the REU mentors post-REU training?
6) Did the REU trainees publish any abstract/poster/paper with the REU mentors post-REU training?
7) Did the REU trainees have any professional community activities during and post-REU training?

REU Experiences Survey

REU experiences survey (Table 1) was conducted 10 years ago before the REU trainees left the REU site. Part 1 of the survey was designed to examine the research related skills of REU trainees. The responses were quantified with 6 scales. Part 2 of the survey focused on the support to REU trainees with respect to the REU PI and mentor's availability which was quantified at 3 scales. Part 3 of the survey focused on research-related activities including field trips and seminars, which were also quantified at 3 scales. Part 4 of the survey was an open-ended question to examine the REU trainees' understanding of their research, which was not evaluated in this research.

Assessment Methods

For the 26 former REU trainees, their demographics, if they are first-generation college students or not, and GPA were extracted from their application materials. Their evaluation of the REU experiences was obtained from their REU exit survey. Their final degree earned, career choices were extracted either from the 10-year post-REU survey or their LinkedIn Profiles. Since most answers to the 10-year follow-up and engagement survey are fact-based, we score each question in the survey as 0 for "No" and 1 for "yes". The degree outcome was also quantified as: bachelor's degree for 1, applied MS degree but not earned as 2, MS or Ph.D. degrees as 3. All quantified measures for the 26 REU trainees were analyzed with respect to the average and standard deviation. Correlation analysis was conducted based on the REU trainees' final degree earned and the overall engagement score, and the evaluation score of each engagement criteria.

As a control group, 26 undergraduate students registered in a core course of Electrical Engineering at UTSA, the REU home institute, in 2015-2016 were selected with the following criteria. 1) Students in the control group have no undergraduate research training experiences. 2) The average GPA of the control group is similar to the GPA of the REU group. The 2015-2016 academic year was selected to make sure that the control group has enough time for their career

choices and training time for advanced degrees. A one-tailed t-test was performed with unequal variances to assess the degree outcomes between the REU group and the control group. Statistical significance was established with a p-value less than 0.05.

Table 1. Exit Survey of REU Trainees

***P*art I - Thinking and Working as a Scientist and Applying Knowledge to Research Work.**						
How much did you GAIN in the following areas as a result of your current research experience in the Lab and other related activities?	No Gain	Little Gain	Moderate Gain	Good Gain	Great Gain	No Reply
1. Writing scientific reports or papers. 2. Making oral presentations. 3.Defending an argument when asked questions. 4.Explaining my project to people outside my field. 5.Preparing a scientific poster. 6.Keeping a detailed lab notebook. 7.Conducting observations in the lab or field. 8.Using basic algorithms to analyze data. 9.Working with computers. 10. Understanding Engineering journal articles. 11.Conducting database or internet searches. 12.Managing my time. 13. Understanding basic concepts of robotics.						

Part II - How is Your Research Support?	Always	Most of the time	Rarely/ Never
Part II a- Regarding your UTSA PI (PI Name: _____Various_____) 1. Available when needed. 2. Responds to communications (e-mail, phone call, personal visit, etc.). 3. Supportive of your efforts.			
Part II b- Regarding your UTSA Research Mentor (Research Mentor Name:_____Various_____) 1. Available when needed. 2. Responds to communications (e-mail, phone call, personal visit, etc.). 3. Supportive of your efforts.			

Part III - Your Assessment of Other Research-Related Activities	Very Good	Somewhat Useful	Not Useful
1. Field Trips 2. Research Seminars			

Part IV - What is Your Research Topic? Please Describe How it is Progressing.

Results

Demographics of REU participants

Twenty out of twenty-six REU trainees majored in Electrical and Computer Engineering, with 2 trainees in Computer Technology, 1 in Engineering Management, 2 in Computer Science, and 1 in a double major of Computer Science and Mathematics. In their exit survey, 10 out of 26 expressed their intention of joining graduate schools. Specifically, their average GPA when they applied for the REU program was 3.44 out of 4. Since the goal of the REU program was to foster research interest in underrepresented students, we did not choose REU trainees based on their GPA. Instead, we put more emphasis on underrepresented, female, and first-generation college students. It's worth mentioning that 75% of this REU trainee group was female or underrepresented minority students. About 50% of this REU cohort was first-generation college students. Three trainees are female students. Demographics and locations of REU trainees' institutes were shown in Figure 1.

Results from 10-year follow up Survey

The 10-year follow-up survey showed that 7 out of 26 REU trainees (26.9%) received doctoral degrees: 1 in Biomedical Engineering from REU home institute (UTSA) in 2015, 1 in Mathematics and Statistics from University of Maryland at Baltimore County in 2015, 1 in Electrical Engineering from Wright State University in 2016, 1 in Computer Science from the University of Illinois at Urbana-Champaign in 2018, 1 in Automation and Robotics from the University of Politecnica de Madrid in 2019, and 2 in Electrical and Computer Engineering from UTSA in 2017 and 2021. Among these 7 trainees with doctoral degrees, three of them are working in academia as research scientists or Assistant professors. Besides these 7 REU trainees with Ph.D. degrees, 4 out of 26 REU trainees (15.4%) pursued master's degrees all in Electrical Engineering from the REU home institute with the REU PIs. Among these 11 REU trainees with advanced degrees, 8 of them are Hispanics or African Americans, 2 Asian, and 1 Caucasian. More interestingly, 8 of them are first-generation college students. In summary, all REU trainees

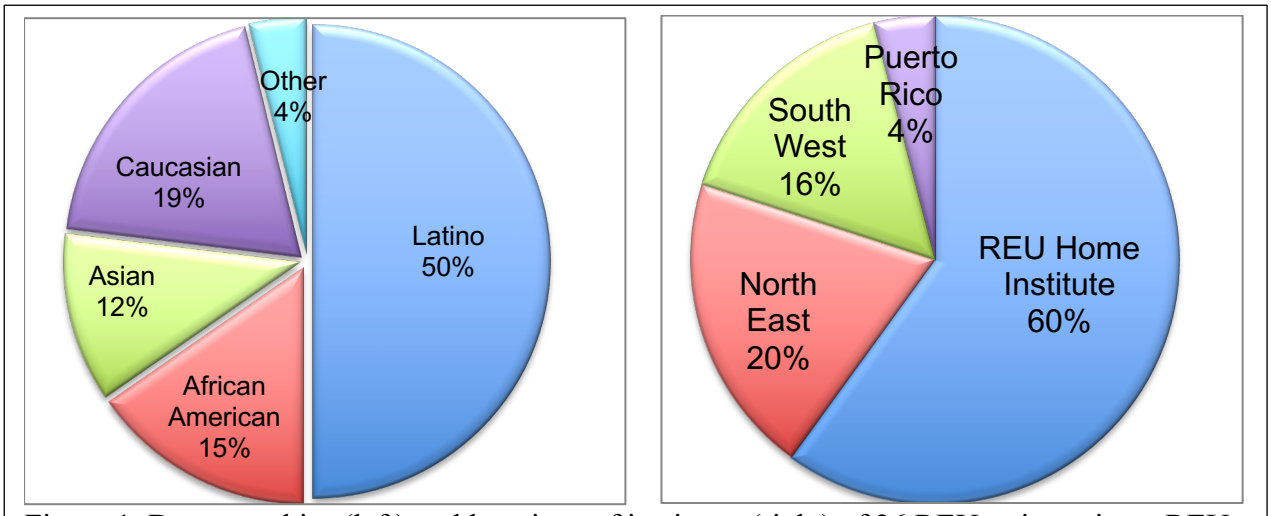

Figure 1. Demographics (left) and locations of institutes (right) of 26 REU trainees in an REU program hosted at UTSA from 2007-2010.

received their bachelor's degree and 42.3% of them earned an advanced degree post-REU training. In addition, 2 REU trainees applied and were admitted to graduate schools post-REU training but did not earn their advanced degrees. Unfortunately, no female REU trainees pursued an advanced degree in this REU cohort.

We compared the degree outcomes of this REU cohort to three facts. 1) Hispanics and African Americans earn 10.8% (6.1% for Hispanics and 4.7% for African Americans) of master's and doctoral degrees in all engineering fields [10, 11]. 2) Hispanics and African Americans earn 13% of master's level and 9% of doctoral degrees in Science and Engineering fields based on an NSF report in 2016 [12]. 3) Degree outcomes of a control group with 26 undergraduate students from UTSA, the home institute of the REU site, were collected and 7 out of 26 students in the control group earned advanced degrees.

A total of 11 out of 26 (42.3%) in the REU trainee group earned master's or doctoral degrees, and 8 out of those with advanced degrees are underrepresented students, resulting in a significant improvement in encouraging underrepresented students for an advanced degree compared to facts 1 and 2 reported by the Census Bureau in 2018 and NSF in 2016.

Comparison among REU group and control group in the Electrical and Computer Engineering from the home institute of REU site (Fact 3)

Table 2. Characters of REU group and the control group in this study.

	REU group	Control group
Number of Students	26	26
Number of Males	23	24
Number of Females	3	2
Underrepresented student %	75%	70%
MS Degree	4 (15.4%)	4 (15.4%)
Ph.D. Degree	7 (26.9%)	3 (11.3%)
Average ± SD of overall GPA	3.44±0.5	3.41±0.47

The REU group and the control group have the same number of students and similar male and female composition, percentage of underrepresented students, and GPA. The percentage of the control group who earned MS (15.4%) degree is similar to 13% as reported by NSF and the percentage for Ph.D. level (11.3%) is also similar to the 9% reported by NSF report [12]. It's worth to mention that 11 out of 26 REU trainees earned master's or Ph.D. degrees while only 7 students from the control groups earned an advanced degree, a significant 57% of the increase in degree outcome from the REU group.

Results from engagement measurements

The average of our engagement score was 3.6 with a 1.3 standard deviation. We quantified each engagement measure as 1 score. The degree outcome was also quantified as: bachelor's degree for 1, applied MS degree but not earned as 2, MS or Ph.D. degrees as 3. The correlation of degree outcome and the overall engagement score was 0.73. It's interesting to mention that the

strongest correlation (0.83) with trainees' degree outcome was joint publications of trainees and REU mentors, following up with contact frequency with the mentor post-REU, 0.6.

All 11 REU trainees with advanced degrees kept frequent contact with the REU PIs during the following years either on undergraduate advising, graduate school applications, career hunting references, and scholarship recommendations. All 11 REU trainees who earned advanced degrees and two trainees who applied to graduate schools had at least one conference paper on their REU research topics. No correlation was found between the degree outcomes and the undergraduate institutes of the trainees. A moderate correlation was found between degree outcome and professional community activities (0.55).

All four REU trainees with master's degrees received their MSEE degrees from the home institute of this REU site. Three of them were undergraduates at the REU home institute. All 4 MS students did MS thesis with the REU PIs, suggesting very strong engagement with the REU site. For the 7 REU trainees with Ph.D. degrees, all of them joined graduate within a very short period of time after they received their bachelor's degree. Specifically, 3 REU trainees moved and joined the graduate school at the REU home institute for their MS and Ph.D. degrees. It seems that 2-year post-REU training is a critical time for REU trainees to apply or continue graduate schools, suggesting possible windows for the REU PIs to follow up and communicate with the trainees for career development choices.

REU Experiences Surveys

Over 80% of 26 REU students give positive responses to the research skills they gained in the REU training. Over 95% of REU trainees give positive responses to the availability of the PI during the REU training and support to their research. In addition, all REU trainees give positive evaluations of the field trips and seminars. Since the REU experience survey was an anonymous survey, no correlation analysis was conducted for REU experiences and degree outcomes.

Conclusion

This is the first longitudinal study on an assessment of the benefits of REU in Electrical and Computer Engineering, providing insight into the role of research experiences prior to graduate school in the transition of REU trainees into their professional career development. The findings strongly support that engagement of REU trainees provides thrust in their transition to graduate schools. Specifically, joint publications, interaction strength with their REU mentors post-REU training, and professional community activities are the top three contributing factors to the engagement. Interestingly, the thrust is strong within two years post-REU training, a reasonable time point as the REU trainees face the first career choice, academia or industry, post bachelor's degree. The findings of this study also add important evidence in support of the value of REU with fact-based surveys and measurements 10-years post their REU experiences. These measurements are not intention-based or opinion-based, thus providing more confidence in the true outcomes of REU programs. The results of this analysis also provide useful insights to research mentors that active engagement post-REU training is very important to maintain the enthusiasm of research among REU trainees and encourage them to join graduate schools. Further, the findings should also provide insights to the administrators and funding agencies in

allocating resources for promoting long-term retention and enhancement of individuals in STEM careers.

Though most REU trainees agree on the acquisition of research skills, communication skills, and time management skills, no correlation analysis was performed to examine the effect of these research skills on the final degrees the trainees earned. Potential research can be conducted to analyze the impact of research skills on final career choices. This study also has some limitations on the selection of the control group. Our results showed significant improvement on the final degree the REU trainees earned compared to the data from the United States Census Bureau for all fields, NSF report for science and engineering fields, and a specific control group for Electrical and Computer Engineering. However, the control group was chosen from students who majored in Electrical and Computer Engineering within the REU home institute, leading to a possible institution- or region-specific effect. To have a similar GPA as the REU training group, all students with a GPA below 3.0 were not considered since a GPA greater than or equal to 3.0 is a common admission criterion for graduate schools in the United States. Compared with other large-scale REU surveys, the cohort for this study only has 26 students, large-scale longitudinal research is plausible to generate additional values of REU society.

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References

[1] S. H. Russell, M. P. Hancock, and J. McCullough, "Benefits of undergraduate research experiences," *Science,* vol. 316, no. 5824, pp. 548-549, 2007.

[2] D. Lopatto, "Undergraduate research experiences support science career decisions and active learning," (in eng), *CBE Life Sci Educ,* vol. 6, no. 4, pp. 297-306, Winter 2007, doi: 10.1187/cbe.07-06-0039.

[3] D. Lopatto, "Survey of Undergraduate Research Experiences (SURE): first findings," (in eng), *Cell Biol Educ,* vol. 3, no. 4, pp. 270-7, Winter 2004, doi: 10.1187/cbe.04-07-0045.

[4] M. C. Linn, E. Palmer, A. Baranger, E. Gerard, and E. Stone, "Undergraduate research experiences: Impacts and opportunities," *Science,* vol. 347, no. 6222, p. 1261757, 2015.

[5] D. Lopatto, "Exploring the benefits of undergraduate research experiences: The SURE survey," in *Creating effective undergraduate research programs in science.* New York, NY, US: Teachers College Press, 2008, pp. 112-132.

[6] K. Powers, H. Chen, K. Prasad, S. Gilmartin, and S. Sheppard, "Exploring How Engineering Internships and Undergraduate Research Experiences Inform and Influence College Students' Career Decisions and Future Plans," in *Proceedings of the American Society for Engineering Education Annual Conference, June 24-27, 2018. Salt Lake City, Utah.*, 2018.

[7] N. S. F. D. o. U. Science and M. 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.

[8] M. Hanson. "College Graduation Statistics." EducationData.org. https://educationdata.org/number-of-college-graduates (accessed Feb 1, 2022).

[9] "The State of U.S. Science and Engineering 2022," in "Science and Engineering Indicators," National Science Board, January 2022 2022, vol. 2022. [Online]. Available: https://ncses.nsf.gov/pubs/nsb20221

[10] E. L. Anderson, K. L. Williams, L. Ponjuan, and H. Frierson, "The 2018 Status Report on Engineering Education: A Snapshot of Diversity in Degrees Conferred in Engineering," Association of Public & Land-grant Universities: Washington, D.C., 2018.

[11] A. EDWARDS. "Hispanic Poverty Rate Hit an All-Time Low in 2017." https://www.census.gov/library/stories/2019/02/hispanic-poverty-rate-hit-an-all-time-low-in-2017.html (accessed 09/22/2019, 2019).

[12] NCSES. "Degrees earned by underrepresented minorities." NCSES. https://ncses.nsf.gov/pubs/nsf19304/digest/field-of-degree-minorities (accessed.

[13] W. H. Frey. "The US will become 'minority white' in 2045, Census projects." https://www.brookings.edu/blog/the-avenue/2018/03/14/the-us-will-become-minority-white-in-2045-census-projects/ (accessed Feb, 2020).

[14] J. Roy. "Enginering by numbers 2019." ASEE. https://ira.asee.org/wp-content/uploads/2019/07/2018-Engineering-by-Numbers-Engineering-Statistics-UPDATED-15-July-2019.pdf (accessed.

[15] NCES. "Status and Trends in the Education of Racial and Ethnic Groups, Indicator 26 STEM Degrees." National Center for Educational Statistics. https://nces.ed.gov/programs/raceindicators/indicator_reg.asp#r1 (accessed.

[16] J. Mervis, "Student Research: What Is It Good For?," *Science,* vol. 293, no. 5535, pp. 1614-1615, 2001, doi: doi:10.1126/science.293.5535.1614.

[17] R. Ignace, "Quantifying Undergraduate Participation in Scholarly Activities," *Scholarship and Practice of Undergraduate Research,* vol. 3, no. 2, pp. 62-70, 2019.

[18] A. Wilson, "Using the National Survey of Student Engagement to measure undergraduate research participation," *Council on Undergraduate Research Quarterly,* vol. 32, no. 3, pp. 9-15, 2012.

[19] P. R. Hernandez, A. Woodcock, M. Estrada, and P. W. Schultz, "Undergraduate research experiences broaden diversity in the scientific workforce," *BioScience,* vol. 68, no. 3, pp. 204-211, 2018.

[20] M. J. Graham, J. Frederick, A. Byars-Winston, A.-B. Hunter, and J. Handelsman, "Increasing persistence of college students in STEM," *Science,* vol. 341, no. 6153, pp. 1455-1456, 2013.

[21] C. Houser, K. Lemmons, and A. Cahill, "Role of the faculty mentor in an undergraduate research experience," *Journal of Geoscience Education,* vol. 61, no. 3, pp. 297-305, 2013.

[22] D. R. Raman, B. N. Geisinger, M. R. Kemis, and A. de la Mora, "Key actions of successful summer research mentors," *Higher Education,* vol. 72, no. 3, pp. 363-379, 2016.