Board 280: Evaluation of a Three-Year Research Experiences for Undergraduates Site Focused on Engineering Solutions in Support of Communicative Disorders

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Introduction

Participating in undergraduate research is a high-impact practice for enhancing student success [1, 2]. It is useful in promoting collaborative interdisciplinary research efforts [3], raising awareness of the societal context of research [4], engaging under-represented students [5, 6], and improving graduate student recruitment [7]. To provide opportunities for undergraduate students to pursue research, our project team coordinated a 3-year NSF-funded REU site at The University of Alabama (*Sensors, Systems and Signal Processing Supporting Speech Pathology*). We utilized interdisciplinary projects that engaged students in healthcare through developing technology to support clinical practice in the fields of audiology and speech-language pathology. This site supported three summer cohorts of engineering and computer science students to explore research at the intersection of engineering and communicative disorders.

Speech-language pathology is an applied behavioral science that includes screening, assessment, and treatment related to fluency, speech production, language, cognition, voice, resonance, feeding/swallowing, and auditory habilitation/rehabilitation [8]. In clinical practice, Speech Language Pathologists (SLPs) utilize a range of instrumentation and technologies including audio recording/acoustic analysis, electromyography, and video imaging/analysis. Even though the design of instrumentation and technologies in service of clinicians and patients clearly aligns with the skills of engineers, spontaneous collaboration between these two fields does not often occur. Furthermore, while SLPs work directly with patients to understand and deliver on each individual's unique care needs, engineers do not converse frequently enough with SLPs or their patients. Therefore, there is an opportunity to increase collaboration between SLPs and engineers to identify unmet needs in clinical practice and increase communication between these groups.

This work provides an overview of the REU site (building on preliminary reports of experiences [9] that led to its formation and early/midpoint reviews of student activities and feedback [10, 11]) and summarizes three years of reported student satisfaction with the overall REU, research experience, perceived learning gains, perspectives of social responsibility in engineering, and the impact of their participation on interest in future graduate studies. The program elements that would be most successful for cultivating a positive student research experience and elements that would benefit from future revisions were identified to support undergraduate educators in launching or revising their own REU sites.

Summary of REU Site Activities

Three cohorts of undergraduate students participated in our REU at the University of Alabama (UA), with one cohort in each summer of 2019, 2021, and 2022. The program was paused in 2020 due to the impacts of the COVID-19 pandemic. For each summer of the program students attended campus in Tuscaloosa, Alabama for 10-weeks of research, professional development, social, and cultural activities. Participants were expected to spend 40 hours per week in program activities, with approximately 32-35 directly on their research and 5-8 on professional development, social, and cultural activities each week.

The program activities for each summer of the REU included

- One full-day orientation session that introduced participants to each other (with icebreaker activities), program staff, their research mentors, and program expectations (with HIPPA training to support later activities).
- Six professional development workshops (1 hour each) that covered topics including networking, communication strategies, graduate school, resumes, and poster design.
- Two field trips to cultural sites in Alabama which have included the U.S. Space & Rocket Center (Huntsville, AL) and the Legacy Museum / The National Memorial for Peace and Justice (Montgomery, AL) [10].
- Six to eight clinical shadowing experiences (1-2 hours each) at the Speech and Hearing Center to observe clinical practice [9].
- Weekly peer-share sessions (1 hour each) summarizing successes and challenges (**2021, 2022**).
- Weekly wearable sensor workshops (1 hour each) to facilitate a shared learning experience for participants to advance familiarity with sensors and MATLAB (**2021, 2022**).
- An end of program poster session to present summer research results to engineering and communicative disorders professionals.
- A closing BBQ social with REU students and SLP graduate students.

The specific research project of each participant was guided by a pair of faculty mentors, one each from engineering and communicative disorders. The dual mentorship arrangement provided participants with perspectives and expertise from both disciplines. The REU research projects included a variety of foci such as assessment of noise levels in a mobile audiology clinic, image analysis of pediatric patients with dysphagia from videofluoroscopy recordings, assessment of surface electromyography data of oropharyngeal musculature during swallowing events, and characterization of laryngeal tissues electrical impedance.

Summary of REU Participants

Across 3 summer iterations, a total of 33 students from a range of institutions, majors, and divisions participated in our REU program. The complete breakdown of the ethnicity and gender demographics for each cohort are outlined in Table 1.

Table 1: Ethnicity and Gender Demographics	2019 (n=10)	2021 (n=10)	2022 (n=13)	Total (N=33)
	Gender	Gender	Gender	

Ethnicity	Men	Women	Men	Women	Men	Women	
Asian	0	2	1	1	0	0	4 (12.1%)
Asian / White	0	1	0	0	0	1	2 (6.1%)
Black / African American	2	1	2	1	1	2	9 (27.3%)
Hispanic	1	0	1	0	0	0	2 (6.1%)
White / Caucasian	1	2	2	1	1	7	14 (42.4%)
Native American	0	0	0	0	1	0	1 (3%)
Other	0	0	0	1	0	0	1 (3%)
Total	4	6	6	4	3	10	33

In summary, 60.6% of participants identified as women and 39.3% identified as from an under-represented minority group in STEM (URM-STEM). Overall, ~85% of our participants identified as from an under-represented group in STEM (URG-STEM), that is, women and/or students from URM-STEM. This highlights how our program was successful in our goals of providing research experiences for students from URG-STEM.

An additional goal of our program was to provide research opportunities to students from research limited institutions. For our program we applied this classification to institutions that do not grant doctoral degrees in engineering or computer science. The breakdown of the type of institutions that participants attended is given in Table 2, with BS-only and MS-only referring to institutions that only award bachelor's degrees and bachelor/master's degrees, respectively. Overall, 36.4% of or participants were from research limited institutions, very close to our program goal of 40%.

Table 2: Institution Demographics	2019 Cohort (n=10)	2021 Cohort (n=10)	2022 Cohort (n=13)	Total (N=33)
4 Year / BS-only	3	1	2	6 (18.2%)
4 Year / MS-only	1	4	1	6 (18.2%)
4 Year / PhD	6	5	10	21 (63.6%)

Our REU site did not have a focus on upper-division undergraduate students (i.e., juniors, seniors) and invited applications from students in all years of study. The intent was to provide research opportunities to students early in their education careers. This approach was successful with 54% of participants from lower-divisions (freshman, sophomore) and 46% from upper-divisions (junior, senior). The detailed distribution of participants by year of study across our program's 3 years are given in Table 3. A challenge of this recruitment strategy was that cohorts had students with a wide range of engineering skills and backgrounds, and this did have an impact on some program activities (e.g., technical workshops) which is discussed in further detail in later sections.

Table 3: Year of Study	2019 Cohort (n=10)	2021 Cohort (n=10)	2022 Cohort (n=13)	Total (N=33)
Freshman	3	2	3	8 (24.2%)
Sophomore	0	4	6	10 (30.3%)
Junior	6	3	3	12 (36.4%)
Senior	1	1	1	3 (9.1%)

Our program was designed to appeal to students in multiple fields of engineering. For example, assessments of noise and the theory regarding sound/vibration is within the mechanical/aerospace discipline which motivates the recruitment of students beyond electrical/computer engineering to support this type of project. To support the needs of each project mentor, we recruited undergraduate students from engineering (specifically biomedical, electrical, computer, and mechanical disciplines) and computer science. The distribution of participants by major across all the 3 years of the program is given in Table 4.

Table 4: Major	**2019 Cohort (n=10)**	**2021 Cohort (n=10)**	**2022 Cohort (n=13)**	**Total (N=33)**
Biomedical Engineering	0	2	3	5 (15.1%)
Computer Engineering	2	1	1	4 (12.1%)
Electrical Engineering	2	2	4	8 (24.2%)
Other Engineering (General, Aerospace, Mechanical)	2	4	4	10 (30.3%)
Computer Science	4	1	1	6 (18.1%)

Student Satisfaction with REU Experience

To evaluate student satisfaction and perceptions of the REU, students were invited to participate in an online survey by the external evaluation team from the Institute for Social Science Research (ISSR) at the University of Alabama. This survey was a comprehensive assessment of the students' experiences that included both quantitative and open-ended questions. The survey included items measuring students' satisfaction with various aspects of the program, attitudes toward the research and training they received, their perceived impact of the program on their skills and future plans to be an engineer or computer scientist. Additionally, on the final day of the program each summer the evaluation team conducted a focus group during which feedback/discussion from the students was solicited. This focus group feedback was then summarized for the program coordinators.

The level of student satisfaction with various aspects of the REU experience are presented in Table 5 as means generated from the data collected from each cohort by the evaluation team. Students rated their level of satisfaction with specific program features using a five-point scale, where 1=Extremely satisfied and 5=Extremely dissatisfied. Generally, the students were highly satisfied with each of the program aspects evaluated with mean ratings of 2.00 or better for all items. Generally, the most positive scores were recorded for the overall program and overall research experience.

Table 5: How satisfied are you with the following aspects of your REU experience? (1=Extremely satisfied, 5=Extremely dissatisfied)	**2019 Mean (n=8)**	**2021 Mean (n=7)**	**2022 Mean (n=9)**
REU Site program overall	1.38	1.14	1.44
Research experience overall	1.38	1.14	2.22
Research project topic	1.38	1.29	2.44
Development of technical skills	1.38	1.29	1.67
Research mentoring	1.63	1.57	2.22

Table 5: How satisfied are you with the following aspects of your REU experience? (1=Extremely satisfied, 5=Extremely dissatisfied)	2019 Mean (n=8)	2021 Mean (n=7)	2022 Mean (n=9)
Physical conditions in the lab/project environment	1.63	1.57	2.78
Networking opportunities	1.38	1.89	1.67
Group dynamics in the lab/project environment	1.75	1.71	1.78
Weekly seminars	1.50	2.00	1.78
Shadowing experiences	1.63	2.00	2.67
Opportunities for social activities	1.63	1.71	1.33
Organized group activities/field trips	1.88	1.57	1.33
Relevance to career	1.63	1.43	1.89

In addition to rating their level of satisfaction with aspects of the experience, students were asked to rate their level of agreement with a series of statements describing the REU. The specific statements and mean values for each cohort are given in Table 6. Again, students generally gave very positive ratings with lower numbers being more positive.

Table 6: Level of agreement with statements to describe the REU experience (1=Strongly Agree, 5=Strongly Disagree)	2019 Mean (n=8)	2021 Mean (n=7)	2022 Mean (n=9)
Helped me better understand how to do research and interpret findings.	1.25	1.14	2.00
Gave me opportunities to learn new lab skills.	1.57	1.14	1.80
Was enjoyable.	1.38	1.29	1.70
Provided me with opportunities for networking.	1.00	1.43	1.50
Provided me with opportunities for professional development.	1.13	1.43	1.60
Gave me insight into emerging areas of research and challenges in engineering and computer science.	1.25	1.43	1.80
Engaged me in research decision-making.	1.25	1.43	2.20
Will influence my career decision.	2.00	1.43	2.30
Provided me with mentorship.	1.50	1.57	2.00
Was challenging.	1.75	1.86	2.00
Helped me decide if a research-based career is right for me.	1.88	1.86	2.30
Helped me decide if graduate school is right for me.	1.50	2.00	2.40
Helped me decide if engineering or computer science is the right field for me.	1.75	2.00	1.80

Student Assessments of Knowledge Before and After REU

On the post-REU survey students were asked to report their current knowledge and to *reassess* their prior knowledge relating to research, graduate school, and speech pathology at the beginning of the summer. They had previously rated their knowledge in these areas on a pre-REU survey at the beginning of the summer. Rather than an assessment taken prior to the experience, the reassessment aims to get a better estimate of how much they had learned. Some studies have shown that before a learning experience, novice learners tend to over-estimate their understanding of topics and that having them reassess their prior understanding after a program gives a better estimate of how much they have learned [12, 13]. Students rated their knowledge about each individual topic (listed in Table 7) using a 5-point scale of 1=Substantial amount, 2= Fair amount, 3= Moderate amount, 4= Little and 5= Nothing. The mean scores after the REU, the reassessment of prior knowledge, and the difference between the two scores (after minus before) are detailed in Table 7. A negative value for the difference indicates that students felt

they had greater knowledge for that topic after participating in the REU (with larger magnitude values indicating a greater change in knowledge).

Table 7: Participants self-assessment of how much they know/knew about the following (1=substantial amount, 5=nothing)	2019 (n=8)			2021 (n=7)			2022 (n=10)		
	Post	Reass-essing Pre	Mean Diff	Post	Reass-essing Pre	Diff Mean Diff	Post	Reass-essing Pre	DiffMeanDiff
Poster design	1.38	3.50	-2.12	1.43	3.57	-2.14	1.5	3.6	-2.1
Preparing a research presentation	2.00	3.75	-1.75	1.43	3.29	-1.86	1.9	4	-2.1
Interpreting research findings	2.00	3.63	-1.63	1.86	3.00	-1.14	2.0	3.3	-1.3
Presenting research findings	2.00	3.63	-1.63	1.71	3.14	-1.43	1.7	3.9	-2.2
Research Process	2.00	3.50	-1.50	2.00	3.14	-1.14	2.0	3.1	-1.1
Speech pathology	2.38	3.88	-1.50	2.57	4.14	-1.57	2.50	4.10	-1.60
Developing research questions	2.25	3.50	-1.25	2.43	3.57	-1.14	2.25	3.10	-0.70
Evaluating a research study	2.25	3.50	-1.25	2.29	3.57	-1.28	2.5	3.6	-1.10
Finding research articles	2.13	3.38	-1.25	1.86	2.86	-1.00	2.20	2.90	-0.70
Understanding the needs of clinicians and patients	2.50	3.75	-1.25	2.43	3.57	-1.14	2.10	3.80	-1.70
Designing a research study	2.50	3.63	-1.13	2.57	3.86	-1.29	2.60	3.90	-1.30
Technical and scientific writing	2.25	3.25	-1.00	2.29	3.43	-1.14	2.60	3.10	-0.50
Writing a research proposal	2.88	3.88	-1.00	3.14	4.29	-1.14	3.00	3.80	-0.80
Applying to graduate school	2.63	3.50	-0.87	1.86	2.86	-1.00	3.30	4.00	-0.70
Project management	2.63	3.13	-0.50	2.00	2.43	-0.43	2.00	3.00	-1.00
Ethics in science	2.88	3.13	-0.25	2.14	2.57	-0.43	1.90	2.60	-0.70

Students felt they knew more about all items in Table 7 after their participation in the REU (based on all difference scores having a negative value). Reviewing all three cohorts, participants felt they learned the most about poster design, rating their knowledge after the REU more than two points better than before the REU. Students also felt they learned a lot about preparing research presentations, interpreting research findings, presenting research findings, the whole research process, and speech pathology. These items were rated between 1.4 and 1.9 points better after the REU in one or more cohorts. They felt they gained the least knowledge about ethics in science.

To further highlight what students gained from the REU experience in their own words, their responses to an open-ended question, "What did you learn about yourself from this REU experience?" from the end-of-program survey are detailed below:

- *"I learned that while I would like to go to graduate school, since I did enjoy the experience this summer, I do not have to do it right after graduating. Since I am a senior this school year, I think it might be more valuable for me to get a job for a few years first, and then go back to school and advance my education. This is something I was very unsure about before, so it has been very helpful."*
- *"I learned the importance of taking initiative to have fun and make connections with people. I also learned how much I want mentors to be there to encourage me and be proud of the work that I'm doing."*

- *"I can always finish a project as long as I manage my time effectively and keep making progress."*
- *"I learned that maybe graduate school is not a bad thing and that a research job in industry might be something that I am good at."*
- *"I learned that I adapt to change a lot better than I thought. It also boosted my confidence in being able to finish my degree. I have done work that is actually relevant to engineering now. This showed me I am capable of working in this field and dealing with whatever challenges it comes with."*
- *"I learned that I can work independently and under pressure, and now better understand how much I love to learn."*
- *"I struggled with my research at times and really struggled with presenting and things like that, but this program put me in situations to succeed in a safe environment. I loved my experience, I truly did."*
- *"I know I definitely want to pursue some engineering career that more directly affects others/those more in need. Having social relations within the workplace is very important to me in order to feel motivated to do work. Also, my presentation and social skills have improved so much from where I started."*

A common theme among these responses was students' reporting of their increasing confidence in their own technical skills, their abilities to manage their projects, and persistence towards completing their (challenging) research tasks. This captures how these experiences provide opportunities for students to grow their skills and identities as researchers.

Student Feelings Regarding Graduate Studies and Research Careers

To assess the influence of the program on participants' feelings regarding pursuing graduate studies and careers in research, students rated their level of agreement with statements related to these topics. These statements and the distribution of ratings from all participants who completed them (N=25) are given in Table 8.

Table 8: Agreement with statements: The program increased my desire to pursue ...	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Master's degree in computer science or engineering	6	12	4	1	2
PhD in computer science or engineering	3	8	10	3	1
Career in research	3	13	5	3	1

Nearly three-quarters of participants (72%) "Agreed" or "Strongly Agreed" that this program increased their desire to pursue a Master's degree, and close to half "Agreed" or "Strongly Agreed" that the REU increased their desire to pursue a PhD (44%). Nearly two-thirds (64%) "Agreed" or "Strongly Agreed" the REU increased their desire to pursue a career in research. Approximately 4 participants reported that the REU decreased their desire to pursue a career in research. These findings support the conclusion that participation in our REU program positively influenced the majority of participants' perceptions of graduate studies and careers in research. In follow-up data collected from former participants, so far 10 participants have graduated with

their undergraduate degrees and 40% of those graduates are currently enrolled in graduate studies, thus confirming that participants from our program are not just interested in graduate studies but are actively pursuing those opportunities.

Student Feedback Regarding Cultural Experiences

In addition to the research experiences, our program coordinated cultural experiences aimed to provide opportunities for students to interact outside of their labs (fostering a cohort experience) and expand beyond technical training. The specific activities of our program included

- Visiting the U.S. Space and Rocket Museum in Huntsville, AL to highlight the history and contributions of the state of Alabama to space exploration.
- Visiting the Legacy Museum / National Memorial for Peace and Justice in Montgomery, AL to provide a comprehensive history of the legacy of slavery in the United States.
- Completing the self-guided Hallowed Ground Project developed by Dr. Hilary Green [14,15] to outline the "lives, experiences, and legacy of the many enslaved men, women, and children who lived, worked, even died at the University of Alabama, 1829-1865."

One aim of these cultural experiences was to connect the histories of racial injustice detailed at the Legacy Museum / National Memorial for Peace and Justice to the current STEM environment. Our approach and scaffolding for these activities evolved based on feedback from the students collected during the end-of-program focus groups. This feedback from the first and second cohorts (in 2019 and 2021) revealed that further structure and discussion was required to facilitate students' engagement and understanding of these topics. Our initial expectation that students would make connections between the trip to the Legacy Museum and the current state of STEM was implied and we did not make the connections explicit. Nor did we provide supporting activities to facilitate discussions to promote deeper engagement. Although students discussed the idea that the racial biases of the past are still present today in the end-of-program focus groups, they never made the connection between how the biases of the past influenced research in science and engineering today in terms of what questions get asked, whose social problems are "worthy" of solving with science, and what barriers exist for students from different backgrounds to pursue careers in STEM.

For 2022, the final coordination of scaffolded experiences to connect the histories of racial injustice to the current STEM environment included: **1)** two workshops on active listening and civic discourse (delivered by Jackson Harris of the Crossroads Civic Engagement Center, an initiative of the Division of Community Affairs at the University of Alabama) to prepare students for engaging with topics that may make them feel uncomfortable, **2)** visiting the Legacy Museum / National Memorial for Peace and Justice to provide a comprehensive history of the legacy of slavery in the United States, **3)** workshop on "Connecting Histories: Exploring Racism in STEM" (delivered by Dr. Miriam Sweeney of the School of Library and Information Science at the University of Alabama) to engage participants in the histories, politics, and social consequences of engineering (and other technical fields), **4)** completing the self-guided Hallowed Ground Project (developed by Dr. Hilary Green) , and **5)** a final written reflection on their experiences guided as a "3-2-1" writing prompt (What are 3 things that have left an impression on you from your time [participating in these activities]? What are 2 impacts that you think these

histories continue to have on education? What is 1 thing you would want to learn more about related to these topics?).

From the final focus group in 2022, the students reported that the prompt to reflect on past injustices and the Connecting Histories seminar helped them understand the ways in which engineering needs to be inclusive of all people. It appears this approach, which requires an extensive set of scaffolded activities and almost weekly focus, was more effective than previous cohorts and would be recommended for future iterations (and other programs interested in adopting similar aspects in their REU programs).

Student Negative Feelings About the Program

Students were also asked in the end-of-program survey to rank items that contributed to any negative feelings and to describe those feelings. Across the three years of our program when students reported negative feelings they were most often associated with lack of communication with mentors, lack of an organized research plan, and lack of clear direction through the summer. Samples of specific feedback from participants detailing their negative experiences are below:

- *"Have there be more mentor involvement: it's necessary to know how we're doing and what directions we should be going in, and it can become overwhelming if we don't get their input."*
- *"I did not have a great relationship with one of my mentors. They did not provide much meaningful assistance in this project, and there was little contact between us for a vast majority of the program."*
- *"The overall REU was run well but my mentors specifically did not communicate or direct us well. We often times had lulls and full stops in our work because our advisors weren't giving us enough direction to complete a task or they wouldn't communicate with each other to set a clear goal."*
- *"I wish there was more guidance about what to do in the lab -- I was very confused for the first few weeks and wasn't sure if I was doing what I was supposed to be doing the whole time."*

This feedback highlights that many participants had expectations regarding the amount of time they would spend with their mentor, the type of support from their mentor, and the nature of research that were not met. This is an aspect of the program that is challenging to balance based on the different expectations of students and mentors regarding their participation in the program. While our program did provide training on expectations for faculty prior to each summer and for students during orientation, it is clear further clarification on setting expectations was required. For future iterations, pre-summer mentor activities regarding setting and communicating expectations and preparing a schedule of research goals, student learning objectives, and research deliverables could improve scaffolding for the summer. Student training during orientation should also introduce our expectation of participants to transition towards research independence, strategies for that transition, and coping with research results that do not align with expectations.

Engineering Professional Responsibility Assessment Survey

Beyond evaluating students' opinions of research and perspectives on technical skill gains, we also wanted to evaluate participating students' attitudes towards social responsibility and if they changed because of participation in our REU. To facilitate this evaluation, the pre- and post-summer surveys incorporated the Engineering Professional Responsibility Assessment (EPRA) tool. The EPRA tool was developed to help educators assess curricular interventions aimed at changing students' views of social responsibility [16]. This tool assesses eight dimensions in three realms of the Professional Social Responsibility Development Model (PSRDM) which describes the development of both personal and professional social responsibility in engineering students [17]. The eight dimensions are awareness, ability, connectedness (grouped in the realm of personal social awareness); base skills, professional ability, analysis (grouped in the realm of professional development); and professional connectedness and cost-benefits (grouped in the realm of professional connectedness).

For this tool, social responsibility is assessed as: being aware that others are in need, recognizing one's ability to help, feeling a requirement to help others, recognizing that the engineering profession has the ability to help, recognizing the importance of social aspects in the engineering process, and understanding the costs and benefits associated with engaging in ethical actions [16]. The EPRA tool has been utilized to assess changes in the social responsibility attitudes of engineering students over time [18] and differences between disciplines [19].

The primary portion of the EPRA consists of 50 items distributed across the eight dimensions in the previously listed three realms. Participants were asked to rate their level of agreement with these 50 statements using the following 7-point scale: 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, and 7=Strongly Agree. For each of the eight dimensions, a mean of the item ratings was calculated to produce a dimension score for all survey respondents. Negatively worded items (e.g., It is *not* my responsibility to do something about improving society) were coded in reverse (i.e., 1=Strongly Agree; 7=Strongly Disagree), such that higher scores indicate stronger leanings toward a sense of social responsibility. The students' pre and post REU scores are presented in Table 9.

Table 9: Comparison of Mean (n=24) Pre- and Post-REU EPRA scores for each dimension	**Mean Pre-Score**	**Mean Post-Score**	**Mean Diff. (Pre-Post)**	**t**	**p**
Awareness: How aware students are of societal problems	4.39	4.44	-0.05	-0.36	0.70
Ability: Recognition that one has the ability to help others	5.05	5.00	0.05	0.39	0.70
Connectedness: Sense of moral obligation toward helping others	4.77	4.89	-0.13	-1.19	0.24

Base Skills: Importance individual places on base skills (e.g., math, science, management, technical) for professional engineers	6.37	6.38	-0.01	-0.09	0.92
Professional Ability: Recognition of the role of engineers in helping to solve societal problems.	4.11	4.08	0.03	0.34	0.74
Analyze: Recognition of the importance of including societal standards in the engineering process.	5.35	5.48	-0.13	-1.19	0.24
Professional Connectedness: Obligation engineering has towards solving problems in society.	4.79	4.72	0.08	1.12	0.28
Cost Benefit: Cost of engaging in service work in engineering.	5.44	5.36	0.07	0.58	0.57

Paired t-tests were applied to compare the differences between the pre and post REU scores. The specific t-value and p-score for each test are also given in Table 9. From these values there were no statistically significant differences ($p > 0.05$) between the scores on the pre- and post-surveys. This suggests that participation in our REU did not change students' ideas regarding social responsibility.

This lack of change may be a result of selection bias in our set of participants as students who apply to a program focused on engineering solutions to support clinical problems (and by extension clients needing medical/clinical intervention) may already have strong feelings towards social responsibility (motivating their application). This is supported by the relatively high scores on all dimensions (ranging from 4.08 to 6.38 on the 7-point scale) of the survey scores. If this is the case, it would have been difficult to demonstrate significant change. Alternatively, it could also indicate that our program activities, while focused on supporting speech pathology, did not make a strong and direct connection with aspects of social responsibility. Similar to our revisions to the cultural activities, changing students' sense of social responsibility may require more direct and targeted activities than were provided in our program.

Gender differences

Research using the EPRA indicates that women who start as engineering majors have a higher sense of social responsibility than men [20]. Additional research has also shown that experiences students have as undergraduates can impact their sense of social responsibility [18, 21, 22]. Furthermore, engineering students with a high sense of social responsibility tend to switch majors to fields in which they feel they will have a career where they can help people [21], unless they encounter experiences that impact their sense of social responsibility as engineering

majors [20]. Because having positive experiences that impact social responsibility may help retain women and other underrepresented students in engineering, we assessed gender differences on the EPRA.

From the EPRA data collected from our participants, prior to participating in the REU women had higher scores than men in two domains: 1) Base skills (importance of basic skills) and 2) Analyze (importance of social context). After participating in the REU, these differences were no longer present, but women scored higher than men on the connectedness domain (responsibility to help others). Women, but not men, increased their scores on Connectedness from pre- to-post-REU. Women also decreased their scores on Base skills, while men showed no significant change. This may support that REU programs with a social responsibility component (like ours) may provide the specific engineering experiences that prevent students with high sense of social responsibility from leaving an engineering major. However, this requires further specific investigation to study this hypothesis.

For further insight regarding the participants' views concerning social responsibility in our REU, students were asked to describe any events from the REU that influenced their views of community service and social responsibility. Specific feedback from participants (in their own words) is provided below:

- *"I definitely think the Montgomery trip to the Legacy Museum and the Slavery Memorial was the most powerful trip of the REU. It is so necessary for people to learn about this history and its ramifications today."*
- *"My mentor was always willing to talk about issues relating to race, gender, or class in Engineering and how we are still a work in progress trying to achieve equality in STEM. Because of this, I'm far more conscious of the impact my actions and words have. I'm cognizant of the impact my career can potentially have on people and how it's up to me to do what I can to improve society in any way that I can."*
- *"Being able to see patients in live clinical sessions was really eye-opening to me. It allowed me to see how they are directly affected by the session and the people they interact with, as well as, how the clinicians are affected by their patients differently."*
- *"Within the REU, I met people from all over the country. It was good to see how influential the area people grew up in influenced their opinions and what they feel needs the most improvement. We also visited the Civil Rights museum and had talks about Civil discourse. These were very eye opening to new perspectives and how our work affects all communities."*
- *"I think most of the field trips we took really showed me the problems that we have in our community at the University of Alabama and in the state of Alabama overall. The field trips also addressed problems that had never occurred to me because of my background and where I am from."*
- *"The seminars held by Crossroads really helped me understand the importance of communication and how one communicates in order to have fruitful conversations. The tour of Montgomery also sheds light on exactly how heavily social injustices have impacted communities in America in the past and present time."*

Summary

Our 3-year REU site at The University of Alabama (*Sensors, Systems and Signal Processing Supporting Speech Pathology*) provided research opportunities for 33 undergraduate students in engineering and computer science. These opportunities engaged students in the application of engineering research to support clinical needs in speech pathology. Our program was successful in terms of recruiting students from under-represented groups in STEM to participate in research and provide high-quality research experiences, though future iterations could be improved by stronger focus on setting and communicating expectations for both mentors and participants. From our investigation of how our REU site may have impacted participants' sense of social responsibility in engineering, an interesting outcome was that women but not men increased their scores on connectedness (sense of moral obligation toward helping others). This could support that REUs with clinical components could provide the engineering experiences that prevent students with high sense of social responsibility from leaving an engineering major (but this requires future study).

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