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Student Satisfaction and Perceptions of Summer REU Experience in an Engineering/Communicative Disorders Focused Site at Program Midpoint

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Introduction

Participating in a research experience for undergraduates (REU) site provides opportunities for students to develop their research and technical skills, raise their awareness of graduate studies [1], and understand the social context of research [2]. In support of this mission, our REU site at The University of Alabama (*Sensors, Systems and Signal Processing Supporting Speech Pathology*) is exploring research at the intersection of engineering and communicative disorders. Our site has a focused theme of developing technology to support clinical practice in the fields of audiology and speech-language pathology. 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 [3]. In clinical practice, Speech Language Pathologists (SLPs) utilize a range of instrumentation and technologies including audio recording/acoustic analysis, electromyography, and video imaging/analysis. While SLPs work directly with patients to understand and deliver on each individual's unique care needs, engineers are not often in conversation with SLPs or their patients. 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. Therefore, there is an opportunity to increase collaboration between SLPs and engineers to identify unmet needs in clinical practice and increase research collaborations between these groups. This opportunity motivated the design of our REU. Our site has completed two summer iterations in 2019 and 2021, with our program at its approximate midpoint and a final iteration planned for summer 2022. At this program midpoint, survey and focus group feedback from participants has been collected to evaluate student experiences and plan revisions for our third cohort. This work will provide an overview of our REU site (participant demographics, overall activities), reported student satisfaction with overall experience, perceived learning gains, and impact on interest in graduate school. This summary and analysis inform our planned refinements for the Summer 2022 iteration (detailed in this work) towards continuous improvement of the student experience and meeting our site goals.

Summary of REU Site Activities

Participants in our REU at the University of Alabama (UA) travel to Tuscaloosa, Alabama for a 10-week summer program with a mix of research, professional development, social, and cultural activities. Participants are 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 specific research of each participant is guided by a pair of faculty mentors, one each from engineering and communicative disorders. The dual mentorship arrangement is meant to provide participants with perspectives and expertise from both disciplines. The REU research projects include 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

Figure 1: 2021 REU participants at (a) the U.S. Space & Rocket Center (Huntsville), (b) the National Memorial for Peace and Justice (Montgomery), (c) an evening of bowling, and (d) the end-of-program BBQ.

musculature during swallowing events, and characterization of laryngeal tissues electrical impedance.

As noted by Straub in their assessment of REUs, social activities in an REU are an important aspect of programs. They serve to introduce participants to each other and get the group working well together [4]. For this reason, our program includes a range of social activities delivered at multiple timepoints throughout the summer, which we have also reported previously [5]. The typical activities (beyond in-lab research) of our REU include:

- One full-day orientation session that introduces 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 cover 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);
- Six to eight clinical shadowing experiences (1-2 hours each) at the Speech and Hearing Center to observe clinical practice, previously outlined [6];
- Weekly peer-share sessions (1 hour each) for participants to share their successes and challenges from the past week (**2021 cohort only**);
- Weekly wearable sensor workshops (1 hour each) to facilitate a shared learning experience for participants to advance familiarity with sensors and MATLAB (**2021 cohort only**);
- 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 post-conference.

A few of the activities of the 2021 cohort (trips to U.S. Space & Rocket Center, the National Memorial for Peace and Justice, bowling social, and end-of-program BBQ) are given in Fig. 1.

Summary of REU Participants

A total of 20 undergraduate students, shown in Fig. 2, have participated in our REU across the 2019 and 2021 iterations. This total represents students financially supported by our REU and students partially supported by the Alabama Louis Stokes Alliance for Minority Participation (LSAMP) program at UA. The collaboration of our REU and LSAMP program has enabled participation of more students in our program than the initial goal of nine per year and supported the recruitment efforts of our program to solicit applications from a diverse range of undergraduates. It is important to note that our REU site has a specific goal of increasing the number of students from under-represented groups (URG) in STEM participating in research; with a target of 50% of our REU students being from URG in STEM.

Figure 2: (a) 2019 and (b) 2021 cohorts of REU participants at the end-of-program poster presentations.

The specific demographic details of our two cohorts are provided in Table 1. Of the twenty students

who have participated in our REU, nine students (45%) identified as members of an unrepresented minority group (Black/African American=6, Hispanic=2, Other=1) and ten students identified as female (50%); overall 75% of participants identified as members of an URG in STEM surpassing our program goal.

Table 1: Ethnicity and Gender Demographics	**2019 Cohort (N=10)**			**2021 Cohort (N=10)**			**Total**
	Gender			**Gender**			
Ethnicity	***Male***	***Female***	***Other***	***Male***	***Female***	***Other***	
Asian	1	1	0	0	2	0	**4**
Asian/White	0	0	0	0	1	0	**1**
Black/African American	2	1	0	2	1	0	**6**
Hispanic	1	0	0	1	0	0	**2**
White/Caucasian	2	1	0	1	2	0	**6**
Other	0	1	0	0	0	0	**1**
Total	**6**	**4**	**0**	**4**	**6**	**0**	**20**

Our REU site does not have a focus on upper-division undergraduate students (e.g. juniors, seniors) and invites applications from students in all years of study. With this approach, we have been successful in building cohorts with representation from all divisions with approximately 45% lower-division and 55% upper-division students. The detailed distribution by year of study for both 2019 and 2021 cohorts are outlined in Table 2.

Table 2: Year of Study	**2019 Cohort (N=10)**	**2021 Cohort (N=10)**	**Total**
Freshman	3	2	**5**
Sophomore	0	4	**4**
Junior	6	3	**9**
Senior	1	1	**2**
Total	**10**	**10**	**20**

The benefit of this recruitment strategy is our program introduces lower-division students to research early in their academic careers, with the hope that this will encourage their early consideration of careers in research and graduate studies (which may inform courses and experiences they pursue during the rest of their undergraduate studies). However, the trade-off for this choice is cohorts have very different technical backgrounds. Compared with their lower-division peers, upper-division participants have had the opportunity to take more technical courses which often increase their experience and familiarity with lab equipment, electronics/circuits, programming, and technical software (e.g. MATLAB). Therefore, we have found it is important for mentors, when preparing their summer projects, to consider the incoming level of students to set appropriate expectations and scaffolding of training experiences.

We recruit undergraduates from engineering (biomedical, electrical, computer, mechanical) and computer science for our program based on the different needs of each project as set by project mentors. 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. The distribution of participants by major for the 2019 and 2021 cohorts is given in Table 3.

Table 3: Major	2019 Cohort (N=10)	2021 Cohort (N=10)	Total
Biomedical Engineering	0	2	**2**
Computer Engineering	2	1	**3**
Electrical Engineering	2	2	**4**
Other Engineering (General, Aerospace, Mechanical)	2	4	**6**
Computer Science	4	1	**5**
Total	**10**	**10**	**20**

A challenge of our recruitment strategy is that our program cohorts have a wide range of engineering skills and backgrounds, which does impact some program activities (e.g. technical workshops) and that is discussed in further detail in later sections.

Student Satisfaction with REU Experience

To evaluate student satisfaction and perceptions of the REU each year, students are invited to participate in an online survey by the external evaluation team at the Institute for Social Science Research (ISSR). This survey is a comprehensive assessment of the students' experiences that includes both quantitative and open-ended questions. The survey includes 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 the evaluation team coordinates a focus group during which feedback/discussion from the students is solicited and summarized for the program coordinators. These evaluation details are used to identify strengths of the program, potential areas for improvement, and if the program is meeting the target goals.

From the survey results collected by the evaluation team, the level of student satisfaction with the REU experience for both 2019 and 2021 cohorts are presented in Table 4. Students rated their level of satisfaction with specific program aspects using a five-point scale, where **1=Extremely satisfied** and **5=Extremely dissatisfied**. Means are shown in Table 1. Generally, the students were highly satisfied with each of the program aspects evaluated, with mean ratings of 2.00 or better for all items. The best scores in both cohorts were for the overall program and overall research experience.

Table 4: 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)
REU Site program overall	1.38	1.14
Research experience overall	1.38	1.14
Research project topic	1.38	1.29
Development of technical skills	1.38	1.29
Research mentoring	1.63	1.57
Physical conditions in the lab/project environment	1.63	1.57
Networking opportunities	1.38	1.89
Group dynamics in the lab/project environment	1.75	1.71
Weekly seminars	1.50	2.00
Shadowing experiences	1.63	2.00
Opportunities for social activities	1.63	1.71
Organized group activities/field trips	1.88	1.57
Relevance to career	1.63	1.43

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 both 2019 and 2021 cohorts are given in Table 5. Again, students generally gave very positive ratings, with means less than 2 on the 5-point scale, with lower numbers being more positive. All of the students "Agreed" or "Strongly Agreed" that the REU: 1) helped them to better understand how to do research and interpret findings, 2) gave opportunities to learn new lab skills, 3) was enjoyable, 4) provided opportunities for networking, 5) provided opportunities for professional development, 6) gave insight into emerging areas of research and challenges in engineering and computer science, 7) engaged them in research decision-making, and 8) will influence their career decision.

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

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. 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 [7, 8]. Students rated their knowledge about each individual topic (which are outlined in Table 6) using a 5-point scale which corresponded to 1=Substantial amount, 2= Fair amount, 3= Moderate amount, 4= Little and 5= Nothing. The mean scores after the REU and the reassessment of scores for the 2019 and 2021 cohorts are detailed in Table 5. Additionally, the mean difference between the post-REU and pre-REU reassessments are provided. A negative value 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 6: Participants self-assessment of how much they knew about the following (1=substantial amount, 5=nothing)	**2019 (n=8)**			**2021 (n=7)**		
	Mean Score After REU	**Mean Score Reassessing Before REU**	**Mean Diff.**	**Mean Score After REU**	**Mean Score Reassessing Before REU**	**Mean Diff.**
Poster design	1.38	3.50	-2.12	1.43	3.57	-2.14
Preparing a research presentation	2.00	3.75	-1.75	1.43	3.29	-1.86
Interpreting research findings	2.00	3.63	-1.63	1.86	3.00	-1.14
Presenting research findings	2.00	3.63	-1.63	1.71	3.14	-1.43
Research Process	2.00	3.50	-1.50	2.00	3.14	-1.14
Speech pathology	2.38	3.88	-1.50	2.57	4.14	-1.57
Developing research questions	2.25	3.50	-1.25	2.43	3.57	-1.14
Evaluating a research study	2.25	3.50	-1.25	2.29	3.57	-1.28
Finding research articles	2.13	3.38	-1.25	1.86	2.86	-1.00
Understanding the needs of clinicians and patients	2.50	3.75	-1.25	2.43	3.57	-1.14
Designing a research study	2.50	3.63	-1.13	2.57	3.86	-1.29
Technical and scientific writing	2.25	3.25	-1.00	2.29	3.43	-1.14
Writing a research proposal	2.88	3.88	-1.00	3.14	4.29	-1.14
Applying to graduate school	2.63	3.50	-0.87	1.86	2.86	-1.00
Project management	2.63	3.13	-0.50	2.00	2.43	-0.43
Ethics in science	2.88	3.13	-0.25	2.14	2.57	-0.43

Students felt they knew more about all items in Table 6 after the REU, rating their knowledge between 0.25 and 2.14 points higher. Students 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 a research presentation, 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 both cohorts. They felt they

gained the least knowledge about ethics in science, rating themselves just 0.25 to 0.43 points better after the REU in the 2019 and 2021 cohorts, respectively.

Student Feelings Regarding Graduate Studies and Research Careers

To assess the influence of the REU program on participants' feelings regarding pursuing graduate studies and careers in research, they were asked to rate their level of agreement with statements related to these topics. These specific statements and the distribution of ratings for both the 2019 and 2021 cohorts are given in Table 7. Most of the respondents in both cohorts "Agreed" or "Strongly Agreed" with the statement, "The program increased my desire to pursue a master's degree in computer science or engineering," while fewer respondents agreed with the statement, "The program increased my desire to pursue a PhD in computer science or engineering." Still, even without a significant desire to pursue a PhD, most students in both cohorts agreed that the REU increased their desire to pursue a career in research. This supports the goal that REU experiences are positively influencing student perceptions of graduate studies and careers in research. However, follow-up details are required to determine if this change in perception translates into these students pursuing graduate studies or research careers after completing their undergraduate studies. It is also important to note here that our recruitment of lower-division students makes tracking/reporting this challenging. Almost half of participants will not have completed their undergraduate degrees before the end of financial support of our 3-year program which limits resources available for long-term tracking of participants.

Table 7: Agreement with statements: The program increased my desire to pursue ...	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
2019 (n = 8)					
Master's degree in computer science or engineering	3	5	0	0	0
PhD in computer science or engineering	1	3	3	1	0
Career in research	1	4	2	1	0
2021 (n = 7)					
Master's degree in computer science or engineering	2	4	0	1	0
PhD in computer science or engineering	2	2	2	1	0
Career in research	0	6	0	1	0

Student Feedback Regarding Cultural Experiences

We previously reported after the 2019 iteration of our REU that the planning and organization of social activities, field trips, and professional development activities facilitated a positive REU experience for the student participants [5]. From the 2019 program evaluation, students had positive feedback regarding their National Memorial for Peace and Justice visit, supporting the idea that cultural activities focused on challenging and uncomfortable histories can be thoughtfully integrated into STEM research programs.

To expand on this, the 2021 REU iteration included a third cultural activity related to racial injustice in American history and its legacy, the Hallowed Ground Project from Dr. Hilary Green

[9,10]. This self-guided alternative tour of the UA campus outlines the "lives, experiences, and legacy of the many unsung men, women, and children who lived, worked, even died at the University of Alabama." The 2021 REU participants were provided tour materials and guided to explore each of the campus locations of the tour on one Friday afternoon. Following this tour, students were asked to review the resources of #ShutDownSTEM to learn about how issues of racism impact academia [11]. As noted on their website details, "#ShutDownAcademia and #ShutDownSTEM is an initiative from a multi-identity, intersectional coalition of STEM professionals and academics taking action for Black lives" [11]. Their website provides a range of resources including readings specific to aspects of academia, from education, to admissions, to hiring. As a first reading, students were directed to the work of Archer, Dewitt, & Osborne which examines why science careers are less “thinkable” for Black students [12].

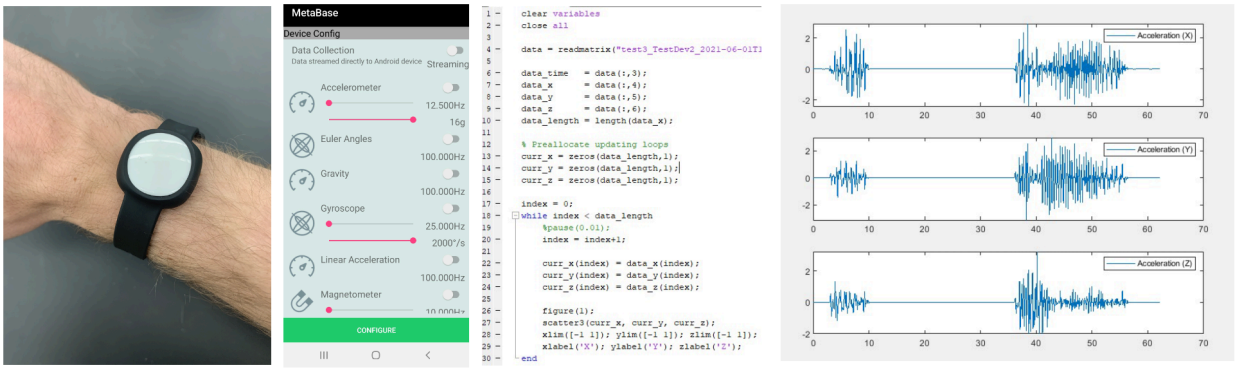
The aim of this tour and independent reading was to give the REU students the resources and time to explore and connect the histories of racial injustice detailed at the Legacy Museum / National Memorial for Peace and Justice to the current STEM environment. However, feedback from the focus group indicated that this was not achieved. When prompted to relate the cultural trips to their lives as engineers in the focus group, one of the students recalled there was a brief discussion about bias in science which led to the students alluding to or discussing different types of biases they have seen in their personal lives and some of the literature they read in their research (but without explicit reference to the #ShutDownSTEM resources). While discussions between the focus group students led them to conclude it is important that people learn about injustices that happened in the past, they thought focusing on science or engineering would take away from the meaning of the fieldtrips.

This feedback supports that further structure and discussion is required in our program to facilitate students’ engagement and understanding of these topics. On review of our approach in 2021, our expectation that students would make connections between the trips and the current state of STEM was implied. 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, 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 our next iteration in 2022, we plan to include a seminar on how scientific bias of the past and present impact scientific research and barriers in STEM [13-16] to help students understand how these ideas are communicated in society.

Student Feedback Regarding Peer-Sharing & Wearable Sensor Workshop

In the 2019 focus group, students were prompted for feedback to the question: "Can you offer suggestions for improvement?" regarding the REU. In response, multiple participants reported that they were alone in their lab throughout their research activities and that this contributed negatively to their experience. While not possible for our program to eliminate periods where participants may be alone due to physical separation of labs across campus and varying availability of mentors/graduate students, we did revise our 2021 iteration to try to limit this feeling of isolation.

For the 2021 iteration, weekly peer-share sessions and wearable sensor workshops were introduced. The primary goal of these additions was to increase the number of activities that students did as a group, requiring them to leave their research labs at least a few times each week with the intent to mitigate extended periods of being alone during research. These activities had secondary goals of increasing communication skills (peer-sharing) and increasing technical skills related to sensor familiarity and MATLAB coding (wearables workshop).



(a) (b) (c) (d)

Figure 3: (a) MetaMotionRL sensor worn on the wrist, (b) smartphone configuration, (b) MATLAB code for importing wearable data, and (d) visualization of 3-axis accelerometer data to highlight activities of the pilot wearables workshop.

Peer-Sharing: For the weekly peer-share sessions the REU participants met as a group with the graduate research assistant supporting the program and the REU coordinators (as available). During this meeting, everyone presented 5-minute summaries of their week with 3-5 PowerPoint slides to support. An approach that helped students structure their peer-share summaries was a "3-2-1" prompt. That is, asking students to provide 3 successes from the past week, 2 questions they had during their research the week, and 1 challenge they struggled with the week. This "3-2-1" prompt can also be modified to focus students on different aspects of their research each week. We noted that by discussing successes and struggles, students were able to see that everyone's research had periods with both elements and that if they were struggling it was a natural part of the research process as they are learning and applying new skills to topics without a fixed answer. Additionally, by discussing challenges the entire group was able to brainstorm potential new paths to pursue to overcome them.

During the 2021 focus group, participants reported that the peer-share sessions helped them feel more comfortable sharing their research, felt they were able to bond with each other, find support with their struggles, learn about their peers' research, and bond with the REU coordinators. This highlights that this activity was incredibly well received and met both primary and secondary goals. As such, the peer-research share will be retained for future iterations of our REU and is a program component we strongly recommend for other REU programs.

Wearables Workshops: For the weekly wearables workshop, the REU participants met as a group with the program graduate research assistant who guided them through activities and assigned tasks to be completed after the workshop to prepare for their next session. These activities included wearable sensor familiarization, importing data to MATLAB, visualization of imported data, collection of motion data during different activities (walking, biking, stair climbing, etc.), literature search for recent human activity focused research, and presentation of selected research publication to the group. For these activities each student was given a

MetaMotionRL sensor (MbientLab, California, USA), a wearable device that offers real-time and continuous monitoring of motion and environmental sensor data with available smartphone application for configuration, data logging, and data downloads. This specific sensor was selected because of its ease of use and previous use by the REU Coordinator (Freeborn) in research related to human activity [17]. Details of the sensor, configuration interface, MATLAB coding and data visualization for a sample dataset used to introduce the students to the workshop are given in Fig. 3. Based on both the disciplinary and division differences of the 2021 cohort, these experiences were designed assuming students did not have any familiarity with MATLAB or sensors. This approach aimed to train students with little to no experience with support from those in the cohort who had already taken courses covering these topics.

From the survey and focus group feedback, the 2021 cohort reported negative feelings towards the wearables workshop. They indicated they did not feel they learned anything from the experience because they felt they merely collected the data from the sensors and plugged it into MATLAB. The students understood why the workshop was included in the program but felt there were several missed opportunities to help them learn to use MATLAB and/or help them learn to visualize data and interpret the results. The students recognized the difficulty of teaching a workshop when some students were proficient in MATLAB and others had only used it for class and suggested that there be "a MATLAB Bootcamp" or scaffolding to provide multiple levels of engagement for students based on their skill level. In addition to improving the way in which MATLAB was used in the workshop, the students also indicated they would like to have been able to discuss how other students collected their data, because they were able to see differences in results and thought that being able to discuss their differences would have been valuable. They also indicated they would have learned more if they had been able to discuss the papers instead of "just presenting them."

While the student feedback provides a path forward for improving the wearables workshop for the next iteration (in terms of aligning the content and material with students' expectations and learning goals), from a programmatic review this activity was succesful in meeting it's primary goal: increasing the number of activities that students did as a group. From the focus group report by the evaluation team, "the dynamics of this group made it clear that they formed a strong bond and they plan to keep in contact with each other after the REU." We believe the increased time and shared experiences as a cohort facilitated by both peer-sharing AND the wearables workshop contributed to this and will keep both sets of activities in our 2022 iteration.

Summary

At our program midpoint, our REU has been successful in terms of meeting our specific program targets based on student feedback collected from student surveys and focus groups. Specifically, providing opportunities for students identifying from groups as underrepresented in STEM to participate in research, providing meaningful high-quality research experiences, and increasing student interest in pursuing graduate studies and research-focused careers. While we do have opportunities to improve activities in our program (e.g. linking the history of racial injustice to the current STEM environment and aligning technical workshops with students' own expectations and learning goals), our program is providing our participants with high-quality learning experiences. To highlight, the following quote from one of the students in the 2021

cohort nicely describes how the REU experience can change a student's perspective on learning:

- "For me this entire time, all I've been doing is going to classes. Whether it was in high school or college, I've just been taking a class and trying to get an A. So, I've had the mindset of a student this entire time. But when it came to [this] research, I wasn't studying for a course. I wasn't going to be tested. I was trying to reach a goal. So the mindset was different. I learned a lot more in these two months than I did in my classes. It was a different kind of pressure. I wasn't learning things to memorize them, I had to learn them to produce things on my own."

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