

Supporting Students with Mobility and Dexterity Disabilities in a Research Experiences for Undergraduates Summer Program

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Eric M. Schearer received a B.S. in mechanical engineering and M.B.A. from the University of Notre Dame, an M.S. in robotics from Carnegie Mellon University, and a Ph.D. in mechanical engineering from Northwestern University. He is an Assistant Professor of Mechanical Engineering and Co-Director of the Center for Human-Machine Systems at Cleveland State University. He is a member of the Bioscientific Staff at MetroHealth Medical Center and a member of the Cleveland Functional Electrical Stimulation Center. His research interests are in restoring reaching and grasping movements to people with paralyzed arms due to spinal cord injury and in training engineers to work with people with disabilities. He previously worked as a consultant at Exponent, Inc., and as an officer in the United States Air Force.

Dr. M. Ann Reinthal, Cleveland State University

Ann Reinthal, PT, PhD has a PhD in neuroscience and practiced physical therapy in a variety of settings before taking a faculty position at Cleveland State University in 1997, where she is currently an Associate Professor. Her research interests are in the areas of motor control and learning, especially as these relate to developing clinical methods to facilitate more effective and cost-efficient motor practice. She is especially interested in integrating the use of technology into rehabilitation for neurologically impaired populations. Her work includes using various commercial video gaming technologies to improve upper extremity function as well as balance. She is also investigating the use of harness systems in balance training and moving this training out of the lab and into a community garden.

Dr. Debbie K. Jackson, Cleveland State University

Dr. Debbie K. Jackson is an Associate Professor in the College of Education and Human Services at Cleveland State University. Dr. Jackson taught chemistry, physics, and physical science in two different high schools before joining the faculty at CSU in 2004. At Cleveland State University, teaching and partnerships are the focus of Dr. Jackson's efforts. Dr. Jackson has extensive experience in curriculum redesign within the teacher education programs and in STEM education. She is currently serving as Program Coordinator for Adolescent/Young Adult (AYA) and K-12 Foreign Language teacher licensure programs and teaches and supervises students in the AYA program for mathematics and science teachers. Dr. Jackson also is a co-principal investigator for several grants related to STEM education, teacher preparation, project-based instruction and computer science education. Dr. Jackson serves as the Network leader for the Metropolitan Cleveland Consortium for STEM Regional Ohio STEM Learning Network Hub and Co-Director of the Center for Innovation in STEM Education.

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Introduction

In the United States, people with disabilities are underrepresented in both engineering education and practice. 4.3% of undergraduate students with disabilities major in engineering vs. 5.3% of students without disabilities [1]. 8% of graduate students with disabilities study math, engineering, or computer sciences compared to 8.9% of their counterparts without disabilities [1]. Recent science and engineering graduates without disabilities have a 91% employment rate vs. 89% for recent graduates with disabilities [2]. While the disparity in education and employment between people with and without disabilities may not be alarmingly large in the early career stages, the gap is much larger as people progress past their early careers. Only 65% of scientists and engineers with disabilities are employed vs. 81% employment for scientists and engineers without disabilities [2].

This shortage is especially concerning in rehabilitation engineering, where the need for perspectives of people with disabilities is necessary. In nearly 75 percent of people who need assisted technology there is an abandoning of their devices due to issues of compatibility, triability, and modifications to meet their specific, unique needs [3]. Having more engineers with disabilities who use assistive technology themselves can only serve to make these devices more useful and decrease the abandonment rate of assistive technology.

Undergraduate STEM education has been a topic of concern and research since the 1990s with the publication of several reports from the National Science Foundation [4], the National Research Council [5] [6] and many others. Since these reports there have been many research studies focused on effective teaching practices in STEM generally and for students from traditionally marginalized populations. One study [7] cites undergraduate research opportunities as a way to engage students from traditionally marginalized populations in STEM. These opportunities for students from traditionally underrepresented populations positively impact their interest in STEM, exposure to research, career aspirations, STEM identity and self-efficacy. Research experiences and other experiential learning formats are effective means for encouraging persistence of underrepresented groups in STEM fields.

Supporting students with disabilities in research and experiential learning activities is especially challenging. These experiences are generally unstructured and multi-faceted. Standard accommodations made for students in a traditional classroom or teaching laboratory [8] – modifications to standard instruments, additional time to complete exams, modified textbooks,

universal wheelchair accessibility – do not necessarily apply when students are working in varied laboratory environments, traveling to off-campus locations, and have ever evolving work assignments that lack specificity in their definition.

To begin to address these challenges and to make unstructured learning environments more accessible to students with disabilities, we studied the cases of three students with disabilities participating in a summer research experience for undergraduates program. This paper assesses the impact of a summer research experience in rehabilitation engineering on students with mobility, dexterity, and psychological disabilities. We identify specific challenges these students faced and assess the impact of the program on these students with disabilities.

Methods

This study was a qualitative, interpretive study. Qualitative research is used to guide in understanding a situation [9]. In this case, the goal was to understand the experiences of three undergraduate students with disabilities in a Research Experiences for Undergraduates (REU) summer program and to understand the impact of the program on these students. In addition to being qualitative, this research is specifically a case study. A case study is “employed to gain an in-depth understanding of the situation and meaning for those involved” [10]. A case study is also defined as a research study that is a single unit or bounded by something [11]. This case was defined as “the REU student”; each of the three students were treated as an individual case and then compared in order to discover themes across the cases. We used comparative case study methods which “strengthen the precision, the validity, and the stability of the findings” [12]. In cross case analysis the possibility for maximizing patterns increases [13]. Cross case analysis seeks similarities among cases, rendering the findings for each case more salient. Cross case analysis was employed in this research as a method of beginning to generalize about the experiences of the REU students. The cross case analysis in this research is more than a summary of findings; it includes detailed analysis necessary to make generalizations. Miles and Huberman [12] caution against a mere summary of findings and insist on looking carefully at the complexity of each case. Merriam [10] suggests that qualitative case studies are particularistic (focus on a particular phenomenon), descriptive (end product is a rich description), and heuristic (enlighten the reader’s understanding). In order to satisfy these outcomes the participants were surveyed, participated in focus groups, and were interviewed. In addition to the information from the students, this case study report also includes notes from the project staff about specific accommodations. Students profiled in this case study gave their consent to participate, and data was collected in accordance with Cleveland State University institutional review board protocol IRB-FY2017-169. There was one student who did not consent to participate in this part of the project; he did not sign a follow up consent form.

Description of the Program and Participants

To give context to the experiences of students with disabilities, Table 1 shows the demographics of all 25 students participating in the summer REU program in two cohorts. Of these students 13 majored in mechanical engineering, seven in biomedical engineering, three in computer science, one in physics, and one general engineering. Two students were rising sophomores, 14 students were rising juniors, and nine students were rising seniors.

Table 1: REU Cohort Demographics

| | Female | Male | African American | Hispanic | Native American | Pacific Islander | White | Persons with Disabilities | Veterans |
|----------------|--------|------|------------------|----------|-----------------|------------------|-------|---------------------------|----------|
| Cohort 1, N=12 | 7 | 5 | 2 | 2 | 0 | 0 | 8 | 1 | 1 |
| Cohort 2, N=13 | 7 | 6 | 4 | 2 | 1 | 1 | 5 | 3 | 1 |

The REU program included a supervised research project, living together in a dormitory, a weekly seminar, presentations to high school students, optional outside activities, and presentation at an external academic conference. Each student worked 40 hours each week in a research lab at Cleveland State University under a faculty advisor. Lab activities included literature searches, electronic and mechanical design, selection of materials, designing and conducting experiments with human participants, computer programming, and documenting their work. Occasionally lab work required visits to indoor and outdoor off-campus locations. Each student lived in a private bedroom and shared a living area, kitchen, and a bathroom with three other students in the program. Students attended weekly seminars with topics including program expectations, written and oral communication, ethics, graduate school, the experiences of people with disabilities, and job search strategies. Students created and delivered presentations for local high school students at the end of the summer program. Students made optional visits to local hospitals, prosthetics manufacturers, and disability-related cultural events. Most students submitted a research abstract and presented a poster at an external academic conference in the fall following the summer REU program.

Each student interacted regularly with the program co-directors, her/his research advisor, other undergraduate and graduate students working in their laboratory, and a program coordinator. Students also interacted with a program evaluator, various presenters at weekly seminars, and dormitory staff. Students with disabilities interacted with Office of Disability Services staff.

The program co-directors designed and oversaw the execution of the summer REU program. One co-director (Eric Schearer), referred to as the mechanical engineering co-director, an Assistant Professor in Mechanical Engineering, initially conceptualized the REU program. His academic training is in mechanical engineering and robotics, and he does research in developing neuroprostheses to restore reaching movements to people with high cervical spinal cord injuries. He interacts regularly with a small group of people with spinal cord injuries, but otherwise has limited experience working with people with disabilities. The other co-director (Ann Reinthal), referred to as the physical therapy co-director, an Associate Professor in the Doctor of Physical Therapy Program, was recruited due to her clinical background working with individuals using a wide variety of assistive technologies along with her extensive experience mentoring undergraduate students in the research laboratory. Both strongly believe that successful rehabilitation engineering involves an interdisciplinary team of engineers, health care clinicians, and technology end users. They also believe that small mentored research experiences are a successful means of engaging undergraduate students in their education and developing career paths.

The co-directors were intimately involved in the design and execution of the summer REU program. They selected each cohort, made personal phone calls inviting selected students,

Table 2: Schedule of Data Collection

| Instrument | Cohort 1 | Cohort 2 |
|---|---------------|--------------------------------|
| survey of knowledge of, motivation to pursue, and preparedness for a career in rehabilitation engineering and/or assistive technologies | June 2017 | June 2018 |
| | August 2017 | August 2018 |
| | December 2018 | will be given in December 2019 |
| focus groups | August 2017 | August 2018 |
| individual phone interviews | December 2018 | will be given in December 2019 |

assigned students to their respective labs for the summer, and served as research advisors to students in both cohorts. They assisted with the students' arrival to campus and orientation. Both co-directors designed and participated in the seminars and handled day-to-day issues that could not be addressed by the program coordinator. The physical therapy co-director arranged and attended many of the outside activities and attended an outside conference with four students in the first cohort. The mechanical engineering co-director worked with the Office of Disability Services to provide accommodations for students with disabilities, organized the final high school presentation day, and attended a conference with twelve students in the second cohort.

The program evaluator (Debbie Jackson), an Associate Professor of Teacher Education, was the team member most removed from the students and the program. Her only interaction with the participants was to give the pre- and postsurveys and conduct the interviews and focus groups. During the second summer, she also facilitated one, 1-hour seminar for the participants in order to prepare them for the presentation to the high school students. The program coordinator arranged housing, payment, and transportation for all students. She had many informal conversations with students in person, on the phone, and by email before, during, and after the summer program.

Data Collection

The data collected for this study included surveys, focus groups and interviews from the students and notes from the team members. The surveys contained 31 statements of confidence. 17 statements were derived from the student outcomes from the Accreditation Board for Engineering and Technology (ABET) [14]. For example, "I am confident in my ability to apply knowledge of mathematics, science, and engineering." 12 statements were derived from select items in the Evaluative Criteria for Accreditation of Physical Therapy Programs (CAPTE) [15]. For example, "I am confident in my ability to exhibit caring, compassion, and empathy in providing services to patients/clients." The two remaining statements were "I plan to pursue a career in assistive technologies" and "I plan to pursue a career in rehabilitation engineering." The students indicated their confidence on a Likert scale from strongly agree to strongly disagree. The focus group questions included questions about the program overall as well as each component of the program. The schedule of data collection events is summarized in Table 2.

In addition to the confidence statements, the cohort 2 students responded to the following statements on the pre- and postsurveys:

- I plan to continue to pursue opportunities to learn more about engineering and computing in rehabilitation and assistive technologies.

- I am good at engineering and computing in rehabilitation engineering and assistive technologies.
- I am interested in taking more classes that involve engineering and computing in rehabilitation and assistive technologies.

Individual Cases

The experiences of three students with disabilities are the focus of this paper. We refer to the students with pseudonyms to protect their anonymity. In general the three students with disabilities participated fully in the program. They worked each day in their assigned labs, lived in a dormitory with other students, attended weekly seminars and outside activities, submitted conference abstracts, presented to high school students, and attended external conferences.

Each student had the opportunity to discuss accommodations over the phone with a member of our Office of Disability Services after being accepted into the program. In some cases, this was a series of phone discussions. Based on these phone discussions, some dorm room modifications were completed before the students arrived, such as installing the necessary door-openers. On arrival, in conjunction with the students and their families, room set-up was reassessed, and other necessary adaptive equipment installed. Typically this was brought from home by the students. The physical therapy co-director, who is familiar with various environmental modifications, was present at move-in for all the students. This was in case additional equipment and/or modifications needed to be accessed immediately, since move in day was over the weekend when the Office of Disability Services was closed. In all three cases dorm living accommodations proceeded smoothly based on preplanning.

Brad

Program Participation. Brad, a rising senior majoring in mechanical engineering, participated in our first cohort. Brad is a veteran who sustained a thoracic-level spinal cord injury several years prior to participation in the program. Brad uses a manual wheelchair that he can propel with his hands. Brad has full use of his upper extremities. When offered a spot in the program, Brad immediately accepted. He decided to travel to Cleveland in his own adapted car rather than flying in order to be able to move easily around Cleveland. This was his first independent stay away from home since his injury and his first long distance trip across country since his injury; his wife came with him and helped him in his dorm room setup, and then flew home, returning to drive back with him at the end of the ten weeks. They brought adaptive equipment for him to use in the dorm bathroom which allowed Brad to be fully independent in his self-care. Brad lived independently in his dormitory room during the program and was able to access the campus and the greater Cleveland area independently either by wheelchair or his adapted car.

Brad's research project was to design and build a force/torque sensor that can be worn on the wrist by a person with a spinal cord injury. His daily activities included making models in a computer aided design program, speaking with vendors on the phone, selecting and purchasing components for his design, 3D printing some components, and writing software to read his sensor. He worked with another student on this project. His activities were not restricted by his disability. Brad presented a poster at the International Symposium on Wearable and Rehabilitation Robotics in Houston. He drove to the conference and shared a rented apartment with a Cleveland State Graduate Student.

Program Impact. The project team anticipated that Brad would have difficulties in getting around campus and living in the dorm. When Brad completed his post interview (one year after the program took place), he described the experience of living on campus:

Yeah, I really enjoyed that. I thought that was really good that they let us all live on campus. You know, all the students and all the interns that were working on the same program. So they kind of let us have a community even after a normal work during the day go back in. It was, it was really enjoyable. I really was glad they let us live on campus and actually live with the other kids in the internship.

One year after the program Brad did not mention the equipment he brought nor inconveniences with living on campus. In probing a bit, we asked Brad if there were any negative aspects of living on campus and he responded:

No, I didn't have any problems and yeah, it was, it's like CSU is a little different than most schools that I was as familiar with, like how it's like literally built right on the main city drag and so that was nice being so accessible to downtown. You see on Euclid Avenue, you are in the middle of downtown Cleveland. That was really convenient.

Brad did not think of anything about the program that should be changed. When asked if Brad thought he worked with people with disabilities while he was at CSU, this was his response:

Yeah, we worked, with a quadriplegic who was paralyzed from her neck down, so we got to work with her a little bit and she was, besides being disabled myself, she was the only other person I really worked with was a disability that I remember. But I think that was really good to actually be involved with the people that you're trying to support. So I really enjoyed that.

In addition, when asked about if he felt more prepared to interact with people who were different from him he responded "Yes." and then added:

I guess working on a program since we designed for the disabled, you know, whenever I meet somebody with a disability or if I was starting to talk with or converse with a person, there may be awkward silence for a period of time. But I can bring out that during my education I was at a part of a program that supported people with disabilities and a lot of times most people are interested about the program and so that opens up the opportunity for me to talk about it a. And then the fact that I've worked specifically for or done research for the disabled, it makes other people more open and just realize that I understand or maybe there's more of an understanding there so they're more open to talk and just be comfortable around me.

One weekly seminar was a group of individuals who had long-term physical disabilities. Brad found it easy to begin a conversation with a panel member with a spinal cord injury who also served in the military. Brad's interaction with this person and his responses to the interview questions indicate the program may have had an impact on his confidence in talking with people who have disabilities (even though he is disabled himself).

On the presurvey indicating the students' levels of confidence Brad started the program very

confident. Of the 31 likert scale statements about confidence Brad responded agree or strongly agree on all items. On the postsurvey Brad responded strongly agree where he previously responded agree on the following statements:

- I am confident in my ability to solve engineering problems.
- I am confident in my ability to use the techniques and skills necessary for engineering practice.
- I am confident in my ability to use modern engineering tools necessary for engineering practice.

Although the change in the rating for these items is slight, it does indicate a change over the three months occurred in the research lab. Brad also moved from agree to strongly agree on the statement:

- I am confident in my ability to expressively and receptively communicate in a culturally competent manner.

Again, this change is slight, but indicates some change in Brad's confidence around communication from the beginning of the program to the end of the program.

This confidence is also evident in Brad's post interview. We asked if participation in the REU changed his career path. Brad responded:

No, I don't think so. I mean I would, it kind of opened me up to the whole idea of rehab engineering. I hadn't really thought about that, so I started looking more into it. But, with my background in the military as well, I was looking at either, something along the lines of rehabilitation engineering or the defense contracting. The defense contract opened up first and so I just pursued that."

While Brad speaks highly of the REU program and the benefits of participating, he came to the program with a strong efficacy towards engineering in general.

Erica

Program Participation. Erica was a rising junior majoring in biomedical engineering when she participated in the second cohort. Erica was born with Arthrogryposis Multiplex Congenita Amyoplasia, a condition of joint contractures and missing muscles. She uses a power wheelchair and has some difficulty with dexterity.

Upon being admitted to the program, Erica did not immediately accept her spot. While she was enthusiastic about the offer, she had many concerns – primarily with the accessibility of her dorm room – that prevented her from committing immediately. A program co-director assured Erica over that phone that her spot would be held for as long as she needed to feel comfortable about accommodations. She then began discussions with our Office of Disability Services.

Before arrival, based on discussions with the Office of Disability Services, automatic door opening systems were installed to allow access to all parts of her dorm room. One institutional impact of the participation of the students with disabilities was the modification of the dorm room for Erica. These doors will allow regular Cleveland State students or summer program students

who have similar disabilities to live in the dormitory. We realized after her arrival that lab door access had not been addressed; since her lab typically had seven other students present, we made sure that another individual was always present to open doors for her in and out of the lab.

This was Erica's first prolonged time away from home and the care of her family. Her mother arrived with her in her wheelchair adapted van while another family member drove in a separate car in which Erica's mother returned home after the dorm move-in. They brought a significant amount of adaptive equipment to make her bathroom and bedroom accessible. In addition, they brought a small refrigerator for the kitchen which could be placed at a wheelchair accessible height but decided it was not needed after finding Erica could successfully access the refrigerator in the dorm in her wheelchair.

Erica required a caregiver for morning and evening assistance with certain dressing, mobility, exercise, and hygiene needs, and she and her family decided to bring her own paid aide with her to Cleveland for the summer. Her caregiver lived in an adjoining room in her dorm suite. The REU program paid for the dormitory room for the aide. Erica attended all campus program activities without the help of her aide, as well as some local community activities accessible in her power wheelchair. However, she required a driver and wheelchair accessible transport for trips further off campus; she decided to keep her van in Cleveland for the summer. Her auto insurance covered both her caregiver as well as other licensed drivers to drive her van; it also allowed other students to ride with her in her van. Therefore, other students in the REU cohort as well as her caregiver sometimes drove Erica to off campus social as well as REU activities.

What we did not anticipate was that the aide did not know anyone in Cleveland, traveling here from a different state, and did not have anything to do during the day when Erica was working. In addition, the students often socialized together and went to various evening and weekend activities that were within walking, or in this case, power wheelchair distance from campus. These did not require her caregiver to drive her and Erica sometimes preferred to go with the other students but not her aide. This caused some friction in the suite as her aide was lonely and did not have any activities of her own.

In the laboratory Erica worked on a computer simulation of the knee. She wrote software to change the computer model's parameters to minimize the error between the model's prediction of existing experimental data. Erica completed her work satisfactorily despite her inability to type quickly. We did however place Erica in a laboratory that primarily does computer simulation. Erica was intentionally not placed in the group that traveled frequently to a community garden where wheelchair accessibility was limited. Erica attended the Biomedical Engineering Society Annual Conference in Atlanta with several other students in the REU program and a the mechanical engineering co-director. Erica's mother drove her to the conference and attended with her. Erica found it difficult to find a hotel with a room that was accessible to her. She was hesitant to reserve a room because she perceived the cost was high, but reserved the room after reassurance that the program would reimburse her for the hotel room. She presented a poster at the conference, attended talks, and went out to dinner with a group of REU students.

Students attended a number of elective off-campus experiences such as a trip to a local prosthetics company and one to a gym designed for individuals with spinal cord injuries. Erica attended nine out of the eleven activities. On one visit to a local wheelchair dance company, Erica fell out of her

wheelchair while trying a dance maneuver with members of the company and broke her knee-ankle-foot orthosis. The physical therapy co-director contacted a local orthotist with whom she had worked who agreed to see Erica and repair the brace in a timely fashion.

Program Impact. When asked about the outside activities in the focus groups, Erica only speaks about the value they had for her learning and future plans. She does not include in her answers any negative aspects.

The outside activities outside of your lab, they really, really did a good job informing me on the careers within the rehabilitation engineering because I always knew that that's what I wanted to do, but I wasn't sure how to get there or like what the job titles of those things are. And so going to those outside activities outside the lab really helped to understand, get closer to making a decision on what I want to do after my bachelor's degree.

On the presurvey, Erica's confidence was not as strong as Brad's. She disagreed with 7 of the 31 confidence statements. On the postsurvey Erica agreed or strongly agreed with all 31 statements indicating a change in her confidence through participation in the program. Her postsurvey includes 21 strongly agree statements out of 31. Most notable are the statements where Erica started at disagree and after the program chose strongly agree. These statements were:

- I am confident in my ability to design experiments.
- I am confident in my understanding of the impact of engineering solutions in a global, economic and environmental context.
- I am confident in my ability to use modern engineering tools necessary for engineering practice.

This indicates Erica's participation in the program impacted her confidence to do engineering research as well as locate the engineering research in a larger context. In addition to these statements, there are several statements which Erica disagreed with at the beginning of the summer and agreed with at the end of the summer. These statements were:

- I am confident in my ability to apply knowledge of mathematics, science and engineering.
- I am confident in my ability to analyze and interpret data.
- I am confident in my ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
- I am confident in my knowledge of contemporary issues.

These statements further provide evidence that the summer program impacted Erica's confidence in positive ways, in particular around engineering research practices and placing engineering in the larger societal context.

During the focus group, we asked the students if a program like the REU was offered at their university. Erica responded:

My university does have a biomedical engineering degree option, but I don't feel like it adequately gives us experience or education about rehabilitation engineering. They do a good job with bio med but it tends to focus on the chemical side of things, at least from the experience that I have so far. And this program, everything was very new to me and it was very eye opening because this sort of activities aren't available at home for my university. And rehabilitation engineering is like what I've been wanting to do. And so coming to this program was very good.

Participating in the REU program increased Erica's confidence and interest in rehabilitation engineering. Erica also talked about her increase in confidence in coding, problem solving and other things she thinks engineers can do.

And before coming here I was very insecure about my coding skills. I still am like, I don't know if I would be the person you would say, hey, let's get her to code, but I definitely have learned a lot more about coding and the thought process that it takes to find out how you want your script to do what you want it to do and where to start and how to get to the ending point of where you want to be. And I think the atmosphere of my lab did a very good job in just teaching me how to think like an engineer. Like just knowing what's important about my data when I'm looking at my results and knowing what the significant pieces of it are and what it all means. And being able to think through a problem very critically and they just retrained my mind on how to think about a problem. Whereas before I was less efficient on how I was solving problems.

She continues to describe engineering items she learned including optimization and problem solving on her own.

In addition to the confidence statements, cohort two students responded to statements indicating their plans to pursue a degree in rehabilitation engineering. At the beginning and end of the program Erica strongly agreed or agreed with the following statements:

- I plan to continue to pursue opportunities to learn more about engineering and computing in rehabilitation and assistive technologies.
- I am good at engineering and computing in rehabilitation and assistive technologies.
- I am interested in taking more classes that involve engineering and computing in rehabilitation and assistive technologies.

Erica came into the summer program knowing she was very interested in rehabilitation engineering, and this interest remained strong after participation in the program.

Chris

Program Participation. Chris was a rising junior in Mechanical Engineering while participating in the second cohort. After service in the Army he had chronic joint pain and post-traumatic stress disorder (PTSD). Upon being admitted to the program, he immediately signed forms committing to participate in the program. Despite being offered the opportunity, Chris chose not to speak with the Office of Disability Services. He did however request a dorm room on the first floor and a disabled parking space due to his chronic joint pain. Chris drove from his home to Cleveland

rather than flying. Otherwise, Chris lived in the dormitory and participated in the program independently without other mobility or dexterity issues. However, we did not initially realize that his PTSD included hypervigilance. Chris was uncomfortable in crowded rooms and/or rooms with multiple doors or windows, and he preferred to sit alone near the back of a room. This became apparent at our first weekly seminar which met in a small ground floor room with multiple large full-length glass windows and two doorways. As the room filled, two faculty mentors took the remaining seats on either side of Chris, and he became noticeably anxious and uncomfortable, and he moved away to one side of the room near an empty doorway. When a co-director asked if he was all right he revealed his issues with hypervigilance. As a result, we changed our seminar rooms to accommodate his needs when possible; we gave him the room and attendance information ahead of time and allowed him to decide if he needed to miss a seminar due to his hypervigilance. He decided to miss two of the seminars that were in crowded locations and also left the crowded luncheon after the high school presentations. He also chose to participate in only two of the eleven off campus events, fewer than many others in the cohort. Chris spoke about the seminars in the focus group, mentioning “On the other hand, that joint seminars are the ones I didn’t like too crowded for me.” He was not always comfortable during the seminars he attended.

Chris worked on a project to design a powered prosthetic leg. His work included making solid models in a computer aided design program, 3D printing and machining parts, and assembling a prototype. Chris’s work assignments were not affected by his disabilities. Chris attended the Biomedical Engineering Society Annual Conference in Atlanta with several other students in the REU program and a program co-director. He drove to the conference, presented a poster, attended talks, and had dinner with the group at the conference.

Program Impact. On the presurvey, Chris agreed or strongly agreed with 25 of 31 confidence statements. Two of the six statements he continued to disagree with at the end of the summer program. He changed from disagree to strongly agree on the following statement:

- I am confident in my ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.

Chris changed from disagree to agree on the following statements:

- I am confident in my ability to function on multidisciplinary teams.
- I am confident in my ability to participate in organizations and efforts furthering the health and wellness of the public.
- I am confident in my ability to exhibit caring, compassion and empathy in providing services to patients/clients.

The culmination of these statements alongside Chris’s disabilities indicate the program had an impact on his confidence in very particular areas. In addition to the change in these statements Chris decided after participating in the program that he did not plan to pursue further opportunities in rehabilitation engineering. In the presurvey, Chris chose strongly agree but on the postsurvey he chose disagree on the following statements:

- I plan to continue to pursue opportunities to learn more about engineering and computing in rehabilitation and assistive technologies.
- I am interested in taking more classes that involve engineering and computing in rehabilitation and assistive technologies.

Chris did agree to “I am good at engineering and computing in rehabilitation and assistive technologies.” on both the pre and postsurveys. He remained confident in his ability but changed his mind about pursuing an advanced degree or further experiences in rehabilitation engineering.

Cross Case Comparison

In order to further understand the individual cases, the cases were compared to one another. From this analysis three themes emerged: the visibility of the disability, the age and life experiences of the student and the degree of the physical disability.

Invisible/Visible Disabilities. Both Brad and Erica’s disabilities were visible; they both used wheelchairs for their mobility. They willingly disclosed their disabilities and assisted in determining the accommodations they would need. In addition, the physical therapy co-director has particular expertise in working with students with disabilities; therefore, we were able to provide appropriate accommodations for Brad and Erica. While Chris’s chronic joint pain was noticeable, the effects of his PTSD and psychological limitations were not visible. In addition to PTSD not being visible, Chris did not disclose any need for accommodations. This impacted his experience and the activities he chose to participate in. It also may have impacted his participation in the focus group and the lack of data we have from him in that focus group. We will follow up with all of the students with individual phone interviews in December and hope to gain more understanding of this at that time.

Age and Diversity of Life Experience. Brad and Chris, as older students and veterans, had significantly more life experience than Erica. They had lived in varied diverse communities in the military and had experience adapting to new situations. Both had previously thought about using their engineering backgrounds to adapt various technology for injured colleagues.

For example, Chris was acutely aware of his place in the group. During the focus group, he mentioned, “I’m the second veteran to come through and I definitely think you need the older perspective. I literally told my lab partner that I was coding in C++ when he was in diapers because it was true.” Chris was aware of his age as well as his disability and experience. His comments throughout the focus group are short and from the perspective of someone who has had more experiences than most of the students. When talking about his participation in the program he cites his experience as important. “Because sometimes the practical experience helps a lot, especially in mechanical engineering. Practical experience helps a lot.”

Erica’s only life experience away from home was her two years in college, and her mother had accompanied her to her college town to provide ongoing assistance. Her comments during the focus group were richer because so much of what she did, both professionally and socially, was novel for her.

Degree of Physical Disability. Erica’s physical disability – limited use of both her arms and legs –

was the most severe followed by Brad and then Chris. Erica's environment outside the laboratory required the most accommodations including the automatic door opener in her dorm room, a live-in aide, and a modified vehicle that required a driver. The presence of the aide, who is a middle-aged adult, certainly changed the dynamics of the program as the aide was the source of some friction and occupied a room that otherwise would have been for another REU student in the program. In addition, the program staff chose a research project centered around computer simulation rather than another project that would have required Erica to work at a community garden. Brad and Chris did not have limitations on research projects and had far fewer living accommodations. Despite all of this, one could argue based on survey and focus group responses that Erica was the student of the three who was impacted most by the program.

Discussion

In this paper we presented the cases of three students with disabilities who participated in a summer research experience for undergraduates program in rehabilitation engineering. All three students participated in all aspects of the program. Survey, focus group, and interview results show a positive impact on these students. Growth related to living away from home, on-campus, and in a diverse community was most notable with Erica since she was significantly younger and with less life experience as compared to Brad and Chris, who were both veterans and older.

We should note that Chris's hypervigilance due to PTSD rather than his chronic joint pain likely caused him to participate less than others. Chris disclosed his joint pain and asked for a dorm room on the first floor. He did not request accommodations for PTSD symptoms until a co-director noted that he felt uncomfortable in a seminar. It is common for students with cognitive or psychological disabilities such as PTSD to be reluctant to disclose their disabilities and seek accommodations [16]. Both Brad and Erica, who had more "visible" disabilities, were especially willing to discuss accommodations with the program staff and Office of Disability Services.

One factor that assisted in making this program work well for the individual participants with disabilities was programmatic agility. In most cases, once the co-directors or program coordinator became aware of a problematic situation, we were able to adapt (e.g. seminar room changes for Chris) or find a solution (e.g. orthotist visit for Erica). This was possible because of good communication and the varied expertise of the team. On occasion our communication failed. For example, the final focus group was again in the room with two doors and full length glass windows which may have been uncomfortable for Chris. However the program evaluator was not aware of this concern.

While this paper has focused on the individuals with disability in the internship program, we believe, anecdotally, that the biggest impact of the summer was on the non-disabled students. The individuals with disability were accustomed to figuring out how to manage getting around, and in conjunction with some pre arrival modifications, they managed successfully. For example, at no time in the focus group or survey does Erica mention falling or difficulty getting around campus or to activities. However, the other students commented about becoming much more aware of all that living with a disability entails. This was particularly evident because of the rehabilitation engineering focus of the summer.

We attribute the program's positive impacts on the three students with disabilities to four primary factors: 1) The students were motivated to participate in the program and for the most part were

good self-advocates, 2) the program set clear and high standards for student participation and deliverables – nothing less than what was expected of all students was expected of the students with disabilities, 3) the program staff were committed to welcoming students with disabilities and working with an individual student’s needs, and 4) the students lived and worked together in a diverse community in the REU program (see Table 1). These factors for success in our open-ended research environment echo many of the findings and suggestions found in previous studies on supporting students with disabilities [17] [18]. We recommend to readers who plan similar programs that they adopt these program elements.

Beyond these recommendations, we plan to make the following changes to improve the impact of the program on students with disabilities. To improve the “program agility” we discuss above, we will design and implement a written communication plan for each student with a disability. It will include all program team members who work with each student. To enhance the sense of community for students with disabilities we will connect them to peer advocates and a faculty mentor with disabilities. To enhance the knowledge of program staff, we will work with our Office of Disability Services to develop an annual training program for faculty, staff, and graduate students who interact with REU students.

In conclusion, there are many challenges that students with disabilities face when participating in research or experiential learning activities. Via the students’ self-advocacy, high-standards, faculty and staff motivation and proper training, and a community supporting diverse experiences, students with disabilities can thrive in such environments.

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