Board 431: Why Research Involvement Makes an Engaging Learning Experience for Neurodiverse Students

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Abstract

This presentation combines the findings of two closely-related Research Experience for Undergraduates (REU) programs, one which ran from 2015-2019 and was specifically for engineering students with ADHD, and a second program, running from 2022-present, open to neurodiverse engineering students (specifically targeting ADHD, dyslexia and/or anxiety). These programs are inspired by research which links the above neurodiversities to increased creativity and innovation, as well as the ability to visualize complex systems. Both REU programs are inspired by the strengths-based approach to neurodiversity. This model builds an environment which plays to a neurodiverse student's strengths, rather than mitigating their challenges.

This presentation will provide an overview of the sites and present three datasets: 1) the impact of the programs on the participants' confidence as engineering students, 2) how the programs impacted the participants' views of their neurodiversity, and 3) the profound effect exposure to academic research has on these non-traditional learners to understand engineering topics and expand their knowledge base. Consistently, these neurodiverse students reported gaining a deeper understanding of their subject matters after research, and at a significantly faster rate, than they could attain in the classroom.

Our findings provide evidence of a pressing need for a paradigm shift within engineering education to not only accommodate neurodiverse students, but to help them realize their full potential. Doing so not only benefits the student, but allows society to benefit from their unique, non-conventional thinking and innovative ideas, which can push research forward at a faster pace. It is anticipated that sharing this data may lead to a shift within engineering education from a deficit- to strength-based view of neurodiversity. We hope to inspire others to develop similar programs that highlight the mutually-beneficial nature of the ecosystem we have developed through 10 weeks of summer research.

Introduction

Promoting diversity in engineering education is a major initiative of ASEE. In recent years, there has been growing awareness of neurodiversity as an important form of diversity to be celebrated and promoted. This is often forgotten as it is can be "invisible." As such, we may miss out on the potential contributions of neurodiverse individuals, which can contribute to greater social equity, reduced opportunity costs, and greater creativity in the field of engineering.

Too often, nontraditional thinkers struggle within the confines of the traditional engineering education curriculum. A study of college students with ADHD showed that only 3% were enrolled in the college of engineering, whereas 76% of the students reported being in the college of arts and sciences (1). To understand the significance of this finding, we need to compare it to the total percentage of students in each college If the overall student population has a similar distribution, with a small percentage in the college of engineering and a large percentage in the college of arts and sciences, then the statistic may not indicate any significant difference between students with ADHD and students without ADHD in their choice of field of study. However, if the overall student population has a more balanced distribution between the two colleges, this may suggest that students with ADHD are underrepresented in the college of engineering and

overrepresented in the college of arts and sciences compared to their neurotypical peers. Unfortunately, this data on not available. For students with ADHD, traditional engineering programs, which typically focus on structured problem solving and allow little room for creativity, are often overwhelmingly challenging, tedious, and unrewarding (2). In addition, these individuals are academically vulnerable; only 22% of individuals with ADHD attend college, and of those who attend, only 5% to 10% graduate (1). They are more likely to be on academic probation, less likely to attend and graduate from college, and twice as likely to drop out of engineering programs as compared to their peers without ADHD (3, 4). The co-occurrence of anxiety and dyslexia with ADHD significantly impedes students' success, as indicated by their lower likelihood of entering college and higher rates of drop out (5, 6, 7). 25–40% of individuals with ADHD have bidirectional co-occurrence with other conditions (5, 8).

To promote the inclusion of students with ADHD, dyslexia, and/or anxiety in engineering, and thereby increase the diversity of the field, a specialized Research Experience for Undergraduates (REU) Site has been funded by the NSF Division of Engineering Education and Centers. This site frames these attributes as a healthy part of the diverse spectrum of human cognition, and rejects the traditional view that these traits are "disorders" (9, 10). By expanding a customized research program for neurodiverse students, this REU Site addresses national priorities by: 1) providing research training in the transformation of aging infrastructure as an area of critical national need, and 2) cultivating the untapped potential of a significantly underrepresented and underserved population of students in engineering.

This Site provided neurodiverse students with an opportunity to engage in research outside of the confines of the traditional engineering curriculum and interact with other neurodiverse peers. This paper presents successes and lessons learned from the previous program which informed the design of the Site, an overview of participants and the research experience, and the quantitative and qualitative findings from a semi-structured interview and post-program survey of the students' experiences.

Highlights of Previous Program

The offering of the current Site built on the extensive knowledge and experience gained from the administration of a previous REU Site (2, 11, 12), and benefits from the unique expertise of the PIs in the mentorship of neurodiverse students.

The notable achievements of the past participants are indicated by the large number of students pursuing PhD studies after graduation or receiving significant national recognition, including the NSF GRFP Fellowship. However, the success of the site extends far beyond its direct impact on the participants. The program inspired a conversation at the national level about the importance of neurodiversity in engineering and STEM. This was evidenced by its inclusion in the 2017-2018 biennial report of the NSF's Committee on Equal Opportunities in Science and Engineering (13) presented to the U.S. Congress, which states that: "*[s]upported by NSF's Division of Engineering Education and Centers, this REU site is directed by NSF Faculty Early Career Development Program awardee […] to provide undergraduate students with Attention Deficit Hyperactivity Disorder (ADHD) with interdisciplinary research experience in the cyber and physical security aspects of critical infrastructure resilience. […] This effort is changing the*

education paradigm from deficit–based to strength–based and make engineering education more inclusive of diverse learning and thinking styles."

The impact of the program on the personal and professional development of the participants is best described by this testimony from a female participant in 2015, who recently completed her PhD in Structural Engineering: *"[through this program, I gained] Confidence in myself and my abilities, [and r]eassurance that I was capable of being an engineer […]. Before I was scared every day that I wouldn't be able to handle myself in the real world. I'd wake up feeling like a failure because I had so much work to do or I couldn't make it to class […]. Now, I still feel that way sometimes, but I know that I'm just different and I am completely capable of anything. Beyond confidence, I realized that I love engineering and specifically research. It renewed my love for STEM after years of classes that sometimes made me forget why I did engineering"*

The program encouraged many participants to pursue graduate studies. Despite having lower-than-average GPAs, 43% of the REU participants are pursuing graduate degrees in engineering (26% PhDs, 17% MSs). This outcome signifies that the opportunity for neurodiverse students to learn in a style that is more consistent with their unique strengths was positive.

Key Lessons and Adaptations of Current Program

The main change in the program was modifying the research focus of the Site. The multidisciplinary approach of the previous program stimulated discussion and provided a comprehensive overview of the interconnectedness of civil and cyber infrastructure systems; however, spreading students across multiple departments made coordination and encouraging completion of publications challenging. The research theme of the current program was modified to be housed centrally in the Civil and Environmental Engineering Department; however students are welcome from a variety of STEM majors. This allows the PIs to support their research progress directly and work with the research mentors to address complications. Another modification was removing formal lab rotations. In the previous offering, rotations were included that allowed each student to spend one day every week in the other labs featured in the program. However, it was noted through participant feedback that the structure of the lab rotation was too rigid. In addition, it did not allow the students to commit as much time to their project, and scheduling of the rotations before the program began did not showcase exciting experiments in the individual labs. The current program incorporates flexible group lab visits, where students or mentors invite the group based on ongoing lab activities. In addition, participants flourished with flexibility, and often spent more time in other labs given their level of interest on a specific project.

Modifications were also made to the application to encourage non-traditional students to apply. Students were given the option of uploading a Statement of Purpose in written format or uploading a short audio/video file describing their research interests and experience, their goals beyond earning a baccalaureate degree, and how they feel they would benefit from this specialized program. In addition, the PIs found that many applications from those who identified as neurodiverse were partially completed. As such, the PI reached out to these applicants by phone and or email and offered to have a virtual interview in lieu of the Statement of Purpose.

Current Research Experience for Undergraduates (REU) Site

The program experienced a notable decline in qualified applicants in the summer 2022 cycle. The majority of students who applied did not self-identify with any neurodiverse group; thus, they were ineligible. This may be from the multiple year hiatus from the previous Site, lingering impacts of Covid-19, and/or unsuccessful recruitment methods. The current application cycle, which is ongoing, did not have similar challenges. The application is not closed, and has already seen a 300% increase in qualified applicants.

The program combines a ten-week traditional summer REU research experience with close mentorship, specially designed seminars, workshops, and roundtable discussions to address the strengths and needs of participants. The specific objectives of this REU Site are to:

- Provide meaningful research experiences for students in an area of national need and provide research training in big data and artificial intelligence in the context of complex infrastructure systems.
- Increase the number of graduates equipped to address the challenge of aging infrastructure systems.
- Increase the participation of neurodiverse students, including those with ADHD, dyslexia, and anxiety, who have the potential to profoundly contribute to the field but are at high risk of academic failure and encourage these neurodiverse students to pursue research and advanced study.
- Capitalize on the untapped strengths of an underserved population to promote creativity by encouraging novel, transformative, and radical approaches.
- Formally disseminate findings to encourage the engineering community to develop similar specialized programs that cater to underserved groups of neurodiverse students.

Each student was assigned a focused research project relating to both their interests and majors; students were mentored by a dedicated faculty member. A subset of students also worked closely with a graduate mentor. Each Friday afternoon of the program, the students participated in either roundtable discussions, brainstorming meetings, seminars, or workshops as shown in Figure 1.

Week	Friday Workshop Topic	Week	Friday Workshop Topic
1	"Then and Now: Thoughts from Former REU Participants"	6	Joint REU community-building activity, Trivia
2	"Graduate Studies in Engineering, How to Apply, How to Succeed"	7	"How AI and Machine Learning are Revolutionizing Engineering"
3	"Student Stories and Experiences in Engineering Programs"	8	"Technical Writing"
4	"Neurodiversity: State –of-the-Art in Higher Education"	9	"Standing Out in the Crowd: How to Make your Resume/CV Pop"
5	Mid-Program Presentations	10	Final Program Presentations

Figure 1. Schedule for Friday team building workshops.

Participants

Five students (2 male, 2 female, 1 non-binary), aged 19 to 23 (M = 20.60, SD = 1.52) participated in the 2022 REU site. Four participants were White and one Asian, and none indicated they were of Hispanic or Latinx origin. Due to the small number of attendees, specific majors will not be included. Four of the participants had been previously diagnosed with ADHD (one indicated comorbid undiagnosed anxiety) and one participant indicated PTSD with no formal diagnosis. Three participants were receiving formal accommodations at their home university.

Data Collection

Four of the participants completed a post-program survey via Qualtrics and three participants (1 male, 2 female) volunteered to participate in a brief, semi-structured interview conducted remotely via Zoom following the close of the program. The survey and interviews were conducted by the Program Evaluator, a Research Psychologist, who conducted the project evaluation as an external consultant. She has extensive expertise in the areas of neurodiversity, mood and emotion, and creativity (14, 15).

Results and Discussion

Participants responses to a series of questions addressing how participating in the program influenced their experience of engineering (Table 1) suggest that the program enhanced all participants' satisfaction and confidence in engineering (i.e., responses ranged from 4 to 7 on a 7-point scale with all means greater than 5.57), particularly in terms of beliefs in their ability to creatively solve engineering problems (i.e., responses ranged from 5 to 7). Participating in the program had less effect on the students' beliefs in their capability to become a successful inventor (*M* = 5.00, *SD* = 0.82, range = 4 - 6) or entrepreneur (*M* = 3.75, *SD* = 0.50, range 3 - 4). However, this may be because the REU Site did not have programming specifically aimed at these careers.

Table 1. Descriptive statistics for participants' agreement with "Participating in this program has increased my…"

Item	Mean	SD	Min.	Max.
happiness that I chose to major in engineering.	5.75	1.50	4	7
confidence that I will complete my degree in engineering.	5.75	1.26	4	7
confidence that I could find an engineering job after I graduate.	6.00	1.41	4	7
belief that I am capable of making transformational technological advancements.	5.75	0.96	5	7
confidence that I can solve engineering problems in a different way.	6.25	0.96	5	7
confidence in my ability to connect different engineering concepts to solve a problem.	6.00	0.82	5	7
willingness to take a chance, even if I might fail, in order to pursue innovation.	6.75	0.50	6	7

belief that I am capable of becoming a successful inventor.	5.00	0.82	4	6
belief that I am capable of becoming a successful entrepreneur.	3.75	0.50	3	4

Note. N=4, scale ranged from 1 *(strongly disagree)* to 7 *(strongly agree)*

Participants' responses to a series of survey questions addressing benefits of the program more specific to components of the REU Site are shown below in Table 2. The results indicated that: 1) interacting with peers and supervisors who also identified as neurodiverse had a strong impact on participants' self-confidence (M> 6.75); 2) all participants agreed or strongly agreed that the experience is beneficial for improving engineering education for neurodiverse students and that they would recommend participating to other neurodiverse students; 3) students believe that the program will have an overall positive impact on their future educational experiences. Responses to the statement "participating in the research project has improved my interest in engineering" were somewhat lower than all other responses. However, this could be due to participants' high level of interest prior to participating in the program.

Table 2. Descriptive statistics for participants' perceptions about the benefits of participating in the program

Item	Mean	SD	Min.	Max.
Interacting with peers who also identify as neurodiverse has improved my self-confidence.	6.75	0.50	6	7
Interacting with the Principal Investigators of this program, who also identify as neurodiverse…, has improved my self-confidence.	7.00	0.00	7	7
This REU program will help me improve my future academic performance.	6.00	0.82	5	7
Participating in the research project has improved my interest in engineering.	5.00	1.41	3	6
Participating in this REU experience has increased my interest in pursuing graduate school.	5.50	1.29	4	7
Participating in this program helped me reinforce my strengths.	6.25	1.50	4	7
Learning the strengths associated with neurodiversity helped to improve my self-confidence.	5.75	0.96	5	7
I would recommend this program to my neurodiverse peers.	6.25	0.50	6	7
I believe that this REU experience can improve engineering education for neurodiverse students.	6.75	0.50	6	7

Note. N=4, scale ranged from 1 *(strongly disagree)* to 7 *(strongly agree)*

Participants also indicated that participating in the program improved their experience with their neurodiversity (Table 3). All participants indicated that they had more positive views of their neurodiversity from participating in the program (i.e., all positively worded responses ranged

from *somewhat agree* to *strongly agree* and negatively worded responses ranged from *neither agree nor disagree* to *strongly disagree*).

Table 3. Descriptive statistics for participants' agreement with "Participating in this program has made me…"

Item	Mean	SD	Min.	Max.
more comfortable openly discussing my neurodiversity.	6.00	1.16	5	7
view my neurodiversity more as an advantage.	6.00	0.82	5	7
more likely to try to hide my neurodiversity from others.	2.25	1.29	1	4
view my neurodiversity more as a disability.	2.00	0.82	1	3
consider my neurodiversity as a more central part of my identity.	4.75	1.89	2	6
think of my neurodiversity more as separate from who I am as a person.	3.75	1.26	2	5

Note. N=4, scale ranged from 1 *(strongly disagree)* to 7 *(strongly agree)*

Responses to the open-ended survey questions and the semi-structured interview mirrored survey results. Thematic analysis of the interview responses revealed four overall themes in participants' responses, suggesting that participating in the REU Site: 1) helped participants to solidify and confirm their future directions in engineering; 2) provided valuable networking and professional opportunities that may have otherwise been unavailable; 3) increased participants' confidence and self-efficacy by allowing them to demonstrate their capability and focus on their strengths; 4) increased participants' self-beliefs through interacting with others who also identify as neurodiverse. Participant responses illustrating each of these themes are presented below:

1) *"I think the most valuable part was my exposure to doing independent research because I thought I wanted to do it, but I wasn't really sure what it would look like. And now I'm more familiar with how it looks and I'm more interested in going to grad school."*

2) *"I also made really meaningful professional connections and like now I have a network of people at [university]…I think it boosted my resume in a way that would make me more of a good candidate for a doctoral degree… so it's definitely like valuable experience to have on a resume, whereas before I was just kind of a student with an average GPA…"*

3) *"I think the value that I valued the most personally that I got from this was like working with my strengths instead of working to like suppress other things. Um that's not what the educational system is designed to be, it's not… how things go normally so getting the chance to do that was amazing. It really changes your everyday and like makes you feel like yeah you know what this is fine, I'm fine and I just need to work in my own way with sort of things."*

4) "*…my professors and… everyone in the program, you were around them and you saw that they're such… successful people, they're people who care about what they're doing and they're… dealing with things too… they might also be dealing with these things but they're making it work and so can you… they have a better idea on how to navigate these kind of things, because they have very nice, like they're very understanding and they have tips on how to navigate this situation*."

Participant responses also highlighted several areas that may be improved in future iterations of the program: 1) Research supervisors who may have limited availability during portions of the program may consider designating a secondary supervisor where available; 2) More communication and interaction both between the groups within the REU Site (e.g., sharing what the different research groups are working on) and across different REU Sites at the university may help compensate for a smaller number of participants in the program; 3) Having more discussions about neurodiversity towards the end of the program may help students communicate more effectively about these issues (as opposed to earlier in the program, when students may be a bit more reserved with one another); 4) Field trips to relevant engineering firms, if possible, may help to further increase participants' interest in engineering.

Despite these few suggestions, all interviewees indicated that participating in the REU Site was an overwhelmingly positive experience for them. For example, when asked if there was anything about the program that should be different, one participant said, "*Uh literally nothing. I loved this experience. I loved it*…" and when asked what the most challenging part of the program was, another participant said, "*[p]robably leaving… I actually really didn't want to leave*."

Discussion and Conclusions

This paper presents the successes and lessons learned from the past program, an overview of the current program, and the quantitative and qualitative findings from a semi-structured interview and post-program survey of the summer 2022 cohorts' experiences. Key highlights include the survey and interview responses suggesting that the REU Site had a positive effect on the participants' experience with engineering, self-confidence, and self-beliefs. All participants agreed or strongly agreed that the experience was beneficial for improving engineering education for neurodiverse students and that they would recommend participating to other neurodiverse students. They also indicated that interacting with peers and supervisors who identified as neurodiverse had a strong impact on their self-confidence, and that the program helped to reinforce their strengths and view their neurodiversity as an advantage.

The findings from the most recent offering also highlighted areas of improvement for future iterations of the program, such as increasing communication and interaction between the various REU programs across campus and considering field trips to relevant engineering firms. Overall, the current REU Site provides an opportunity for neurodiverse students to engage in research outside the confines of the traditional engineering curriculum and interact with other neurodiverse peers. This helps to cultivate the untapped potential of a significantly underrepresented and underserved population of students in engineering. The REU Site was successful in its goal of providing an inclusive and supportive learning environment for

neurodiverse students, suggesting that further research and programming in this area would be beneficial.

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