



Diversifying the Engineering Pipeline through Early Engagement of Neurodiverse Learners

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Abstract

While a large body of literature suggests that students with Attention Deficit Hyperactivity Disorder (ADHD) possess significant creative and risk-taking potential, they have remained highly underrepresented in engineering programs. Past studies have indicated that students with ADHD have an extremely high risk of academic failure and dropout, and are more than twice as likely than their peers without ADHD to leave university. Traditional engineering programs are failing to attract and retain neurodiverse learners, and thus do not benefit from these students' high potential for creative thinking. The disconnect between the traditional education environment and the abilities of students with ADHD is not unique to higher education. In fact, high school students with ADHD have significantly lower GPAs and are over eight times more likely to drop out of high school than their peers without ADHD. These students are thus significantly less likely to enter college or be admitted into engineering programs. To support the development of a more diverse engineering pipeline, efforts have focused on outreach to high school and middle school students with ADHD with the intention of boosting self-esteem and increasing interest in engineering. Specifically, two pilot programs for students with ADHD have been implemented as part of a research project funded by the Research in the Formation of Engineers program of Engineering Education and Centers of the National Science Foundation. Year one of the pilot program featured a two-week program for high school students with ADHD, while outreach efforts in year two focused on the implementation of a week-long summer program for ten middle school students with ADHD. Program activities featured a range of electrical, material, and structural engineering design activities such as wiring circuits and optimizing composites for strength and cost. These activities were complemented by esteem-building activities, including group roundtable discussions in which participants shared life and academic experiences with peers. The main goal of this program is to increase the participation of an underrepresented group of students in engineering programs by providing a strengths-based approach to ADHD in the context of engineering at a young age.

This paper presents an overview of the high school pilot program, including the design, delivery, reflection, and subsequent redesign of the program to meet the needs of middle school students. Major observations from the middle school program will be presented, along with key program components. It was found that: students with ADHD benefit from a personalized learning environment that is centered around student interests and features flexibility and choice; that interactions with role models and mentors with ADHD in the context of engineering can encourage students to consider engineering as a career path; and that roundtable discussions helped to build relationships between participants. A comparison of the middle and high school programs indicates that the age in which the students were introduced to a strength-based perspective toward ADHD was critical in shaping the participants' perceived belief in their engineering abilities. This shows it is crucial to provide exposure to engineering and strength-based discussions of learning differences early in students' academic careers. It is anticipated that providing such experiences for middle school students with ADHD will lead to larger participation of these students in the engineering pipeline and will promote cognitive diversity in the field.

Introduction

Promoting diversity in engineering education has been a major initiative of both NSF and ASEE in recent years. Encouraging and facilitating diversity and inclusion may contribute to greater social equity, reduced opportunity costs, and greater creativity in the field of engineering. Indeed, there is ample evidence that diversity improves the productivity and creativity of teams through varied perspectives, experiences and interpretations [1, 2]. However, there is little awareness of the potential contributions of neurodiverse individuals, such as those with Attention Deficit Hyperactivity Disorder (ADHD). ADHD has been defined by the American Psychological Association as a neuropsychological condition characterized by a persistent pattern of inattention, hyperactivity, and/or impulsivity [3]. However, ADHD has been shown to be associated with creativity, innovation, and risk-taking, all of which are critical skills for engineers to tackle the multifaceted challenges of the future [4-6]. While these traits are all potential assets in the field of engineering, individuals with ADHD are extremely underrepresented in engineering programs.

One reason for the low prevalence of students with ADHD in engineering programs is that nontraditional thinkers often struggle within the confines of the traditional education curriculum. One study of college students with ADHD showed that only 3% were studying engineering, while 76% were enrolled in colleges of arts and sciences [7]. In addition, only 9.1%-20% of students with ADHD characteristics graduate from college, while students that do not display ADHD characteristics have a 68% graduation rate [8]. The disconnect between the traditional education environment and the abilities of students with ADHD is not unique to higher education. In fact, high school students with ADHD have significantly lower GPAs and are over eight times more likely to drop out of high school than their peers without ADHD [9]. These students are thus significantly less likely to enter college or be admitted into engineering programs. This suggests that students not only are less likely to participate in engineering, but also that students with ADHD struggle within traditional educational environments. Research has shown that for middle school students with ADHD, struggles to complete assignments can lead to lower grades, which then can lead to a lower completion rate of future homework assignments [10]. This discouraging cycle can make students with ADHD feel less capable than their peers when they are forced to function in a one-size-fits-all education system.

Strength-based education practices create opportunities to recognize and support existing strengths and abilities as opposed to focusing on problems or weakness [11]. Such methods are rooted in positive psychology, which encourages a shift away from traditional deficit-based models of mental health [12]. Such programs have been shown to increase student motivation and performance [13]. By working in a strength-based educational setting, students are able to gain an awareness and appreciation of their own strengths and see themselves as valuable, contributing members of a group. For students with ADHD, providing opportunities to learn in a style that is more consistent with their unique strengths may positively affect the recruitment and retention of those with diverse cognitive styles.

To support the development of a more diverse engineering pipeline, efforts have focused on outreach to high school and middle school students with ADHD with the intention of boosting self-esteem and increasing interest in engineering. Specifically, two pilot programs for students

with ADHD have been implemented as part of research projects funded by the NSF Division of Engineering Education and Centers of the National Science Foundation. The first pilot program featured a two-week program for high school students with ADHD, while outreach efforts in year two focused on the implementation of a week-long summer program for ten middle school students with ADHD. This paper presents an overview of the high school pilot program, including the design, delivery, reflection, and subsequent redesign of the program to meet the needs of middle school students. Major observations from the middle school program will be presented, along with key program components. The findings of both programs showed that it is crucial to provide exposure to engineering and strength-based discussions of learning differences early in students' academic careers. It is anticipated that providing such experiences for middle school students with ADHD will lead to larger participation of these students in the engineering pipeline and will promote cognitive diversity in the field.

Although the information presented is not acquired through formal research methods, we believe in the importance of the timely dissemination of these observations to the engineering education community to inform future activities in this area. To maintain objectivity, the information presented includes only observations that are shared by the entire organizing team and program mentors.

Background - Research Experiences for Undergraduates (REU) Program

The REU program was the first formalized attempt to expose students to engineering education in a strength-based setting. The specialized program combined 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. Due to the type of program, only those currently enrolled in undergraduate engineering programs were admitted. Throughout the multiple years of the REU, it became very evident to the PI and program manager that the students required an adjustment period (~4 weeks) before they accustomed to the new environment and felt comfortable sharing out-of-the-box thoughts and viewing their ADHD-associated traits as a potential asset. Most students in the program had experienced significant negative experiences in school and low self-esteem related to their ADHD diagnosis. The round table discussions were particularly telling, with the students recalling pivotal moments in their pre-college education that often negatively impacted their view of self or deterred them from engineering. Overall, it was shown that research is one way to re-excite students about engineering, when traditional courses may not.

While the REU program was successful in increasing participants' confidence, interest in remaining in engineering, and interest in pursuing graduate studies, it became clear that these students had already surpassed immense odds by enrolling in a college engineering program. To enlarge the engineering pipeline, intervention before the college years would be required. To this end, a one-year pilot program for high school students was developed as a supplement to the REU program.

Pilot Program Year 1: High School Program

Overview

Initial efforts to expand outreach to students with ADHD at a younger age were directed to high school students through the implementation of a two-week summer engineering program modeled after the REU. Much like the REU program, the participants stayed on campus for the length of the program. However, due to the age of the participants, the length of the high school program was significantly shorter than the undergraduate program. The program also included a mentorship component, roundtable discussions about common experiences related to ADHD, and creative problem-solving activities in the context of structural, material, and electrical engineering activities. Samples of activities including optimizing the design of composites for strength and cost, and a spaghetti bridge competition.

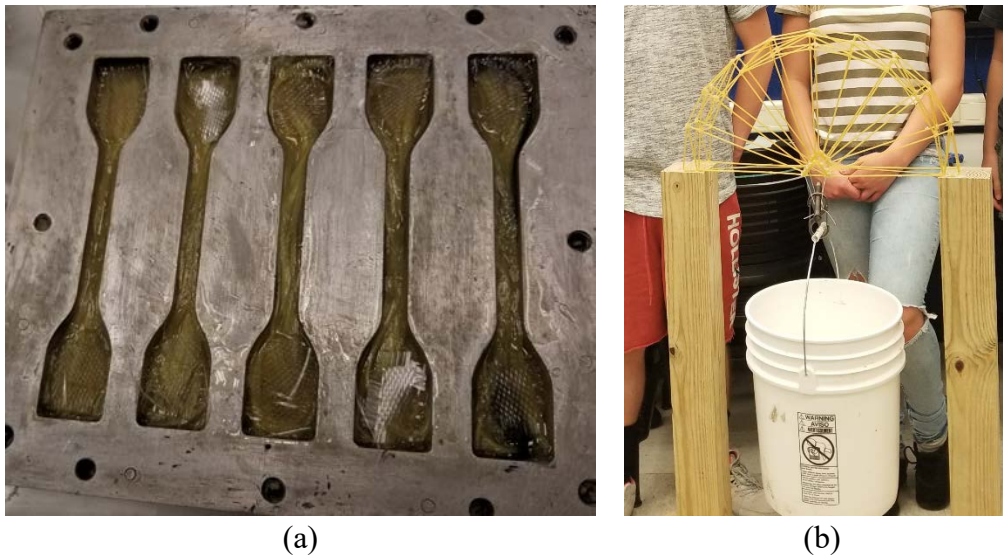


Figure 1. Samples of design challenges for high school program including a) composite challenge and b) spaghetti bridge competition.

Organizing Team

To connect and engage with program participants, it is critical that the program staff and mentors have direct personal experience with ADHD. In particular, the success of this program hinges on the involvement of mentors with ADHD who can both serve as positive role models and share their story with program participants. Program participants have expressed that the involvement of role models with ADHD was of significant benefit to the program.

Our team was led by an engineering professor whose first-hand experience with ADHD led to the development of an REU Site. The team also included two student mentors from the field of civil/structural engineering: one female Ph.D. student and one male master's student. Both mentors had previously been participants in the specialized REU program for undergraduate students with ADHD. The program manager did not have ADHD, but had extensive experience with the strengths-based model through her work managing the REU program and other related projects. Thus, all staff were well aware of program goals and committed to the program outcomes.

Demographics of Participants

The program consisted of five students from across the country. An effort was made to recruit more female students to ensure that the environment did not discourage women from participating in discussions. The final demographics were three females and two males. The age of participants ranged from 14-18, with the majority of students entering their junior year of high school.

Major Observations

Post-program reflections contributed several understandings about the key components of a successful program. The importance of incorporating flexible scheduling, participant interests, and choice into the program became clear, as some participants did not engage in activities that were not of personal interest to them. In particular, activities that were perceived as overly academic or similar to school caused some participants to shut down and disengage. This is not surprising, considering that many students with ADHD experience difficulties with schoolwork, as well as poor relationships with teachers and other school staff [14].

Perhaps the most important observation to be gained from the high school program is that the high school years may be too late for an intervention of this type. Specifically, the length of the summer program was insufficient to effect change. The team felt that the time that was available to interact with the participants was too short to be able to overcome the years of viewing their ADHD as a deficit rather than a strength. This is consistent with our observations of the REU program. Even for college students participating in the REU program, it took more than 4 weeks for the participants' perspectives to shift. After a month in a strength-based research environment, many of the participants began to express that they enjoyed these activities, they were thinking about engineering in a different way, and they were becoming comfortable enough to share in group discussions. It became clear that with a later intervention, more time is needed to make an impact, and to encourage and inspire the participants. For that reason, it was proposed that for a program of short duration (i.e. 1-2 weeks), an earlier intervention might be a more effective approach to reaching students with ADHD.

Pilot Program Year 2: Middle School Program

Overview

Based on the lessons learned through the REU and the pilot program for high school students, a pilot program was implemented for middle school students with ADHD. Great care was taken to support the well-being and self-esteem of the participants and their families during all stages of planning, recruiting, implementation, and follow-ups post-program. All language used during the program was centered around the strengths of students with ADHD.

The pilot program for middle school students with ADHD had three primary goals: 1) create community and support network for students with ADHD, 2) increase self-esteem and confidence for students with ADHD, and 3) increase interest and participation in engineering education by students with ADHD.

Organizing Team

Our team was led by the same engineering professor who developed the REU and high-school programs for ADHD. The team included two student mentors from the field of civil/structural engineering: one female Ph.D. student and one male undergraduate student both of whom had ADHD. The female Ph.D. student had participated in the REU program as a participant and as a mentor in the high school program. The undergraduate student was concurrently participating in the REU. Due to the large enrollment in the program, and the age of the participants, two program managers were used. The first was the same as the manager of both the REU and high school program. The second was a former teacher with extensive knowledge of the program who had co-authored a book with the project PI about the college experience of students with ADHD.

Demographics of Participants

The program participants were five male and five female students between the ages of 10 and 13 who had previously been diagnosed with ADHD. The grade levels of the participants ranged from entering 5th to 9th grade. The gender, age, and grade level of the participants is summarized in Table 1.

Table 1. Demographics of program participants.

Gender	Number	Percent
M	5	50%
F	5	50%
Age		
10	4	40%
11	3	30%
12	1	10%
13	2	20%
Entering Grade Level		
5	1	10%
6	4	40%
7	3	30%
8	1	10%
9	1	10%

Schedule of Activities

The program schedule ran from 8:30 am to 4:00 pm, with approximately 15-minute windows of time at the beginning and end of the day to allow flexibility for parents to drop off and pick up their child. A sample schedule is provided in Table 2. The group gathered outside of the building during drop off and pick up and engaged in informal conversation. There was often an item such as a soccer ball, bean bag, or hacky sack available for physical activity and play during this time as well. While gathered outdoors, the team spent approximately 15 minutes at the start of each day playing simple ice-breakers and name games to allow participants and program staff to get to

know each other. Participants enjoyed these informal ways to learn about each other. The sharing in these games facilitated further conversations between participants later in the day.

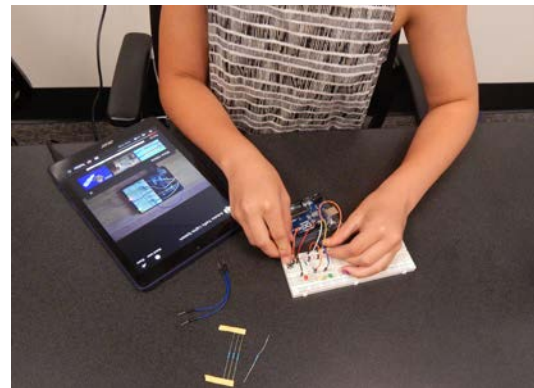
Table 2. Outline of schedule implemented for middle school program.

	Mon.	Tues.	Wed.	Thurs.	Fri.
8:30-8:45	DROP OFF				
8:45-9:30 MEETUP	Ice breakers / Name game / Team-building				
9:30 – 10:00	Introduce/research topic (i.e. bridge types, bridge failures, bridge components, Arduino & sensors, ultra-high-performance concrete, bridge VR)				
10:00 – 11:30	Extension/Exploration of topic (bridge design and construction, beam design and testing, concrete mixing and casting, wiring and coding, additional VR exploration of bridge models)				
12:00 -12:30	LUNCH BREAK				
12:30 – 1:00	GAME TIME				
1:00-1:30	Team-building/Creative problem-solving challenges				
1:30-3:45	Bridge construction project	ROUND-TABLE DISCUSSION #1 – School experiences	Arduino PROJECT	ROUND-TABLE DISCUSSION #2 ADHD strengths Open Choice Projects	Culminating Creative building projects
3:45-4:00	PICK UP				

The morning activities were centered around engineering concepts and skills. Presentations by program staff were kept to a minimum to avoid a teacher-student relationship. Instead, participants were encouraged to research information on tablets that were provided to them as part of the program. For example, participants researched bridge types and components such as beams, as well as Arduino circuits and sensors. They were given materials, space, and time to use this information to build, design, and create. The group was observed closely for engagement. Participants who were deeply engaged in an activity were encouraged and given time to continue their creative work. Participants who had completed their project or were not engaged for any reason were redirected into another activity, or had a mentor join their group to offer encouragement or stimulate ideas and interest. For example, some participants had more need to engage in physical activity than others and preferred to take a 15-minute break for a walk or other outdoors activity from time to time. For this reason, it is highly recommended to have multiple staff members onsite. A program of this nature must be flexible and have options to divide the group depending on the needs and interests of the individual participants. Figure 2 shows the participants engaging in multiple program activities.



(a)



(b)



(c)



(d)

Figure 2. Sample pictures of participants engaging in multiple program activities including a) mixing concrete, b) coding with Arduino, c) building a paper clip bridge, and d) using VR.

The lunch hour was held outdoors whenever weather permitted, allowing ample time for free play and physical activity such as kicking a soccer ball or playing a game of bean bag toss. As one of the primary goals of the program is to build social support and reduce feelings of isolation among participants, we believe that the incorporation of free time for socialization among participants and program staff is key. Afternoon time was dedicated for team problem-solving activities and creative activities that expanded on what was learned in the morning sessions. It should be noted that there was generally an element of choice incorporated into the afternoons. Participants were given 2-3 options to select from and they were also given the freedom to propose a related activity of their own design to the program staff.

Two afternoons were dedicated to holding roundtable discussions about ADHD-related experiences at school and in life. These roundtable discussions are one of the defining characteristics of this program. The group walked to a location separate from the program site for these discussions. For one discussion, the group walked to the local ice cream bar and talked while eating the ice cream outdoors (Figure 3). For the second discussion, the group walked to a location next to a lake on campus and held the discussion in the shade of a large tree. It was found that the participants appreciated the opportunity to be active (walking to the location) and that the activity provided a comfortable context for the participants to talk about their life experiences in a pleasant location. Participation by a mentor with ADHD who shared her

experiences in school allowed the participants to be comfortable with talking about their experiences with their peers. These discussions help participants to understand that they are not alone in their experiences and provide an opportunity for relationship building among participants and mentors alike.



Figure 3. View of participants during round table discussion.

Major Observations

Based on the observations of the high school program, the program was intentionally designed with no formal research component so the participants would not feel as though they were being studied. From observations noted during the program, a post-program reflection, and informal feedback from participants and parents, several key features were identified as contributing to the overall success. Such features are outlined and discussed below:

- **Mentorship-** The central and most important component of the program is mentorship by individuals with ADHD in the field of engineering. Our program featured mentorship by individuals at several different levels in their education and/or career: an undergraduate student, a graduate student, and a professor. The following parent quote shows the impact of positive role models:

“Being around kids and adults that have ADHD and can talk openly about it and be who they are is such a huge thing for kids... I think it’s a great inspiration for the kids to see that people can achieve great success and make modifications as needed, like the fluorescent lights. ...my challenge has always been finding a teacher that would help [him] to open up his mind and use the talents that he has, which is why this camp is so perfect. I can’t even express how appreciative I am for the opportunity for [him] to participate in this great program. I look forward to the opportunity for him to participate in other programs that will further his interest in engineering.”

- **Strengths-based approach-** Students with ADHD often struggle with low esteem due to the stigma related to their diagnosis and negative educational experiences. By emphasizing areas of strength, such as creativity and risk-taking, while acknowledging challenges, participants build self-esteem and realize they are not alone. The following parent quote shows the value of this approach:

“I’m so glad [he] was engaged throughout the week. I so appreciate the opportunity given to him and the other students. Having an ADHD diagnosis made him feel different (in a negative way) from his peers and I believe affects his confidence at times. The experience at the camp the other week somehow “normalized” the diagnosis allowing him to embrace it rather than hide it.”

- **Participant-centered planning-** Observations from the high school program showed that in order to engage participants, it would be necessary to incorporate their personal interests. Prior to the program, participants completed an interest form summarizing their likes, dislikes, strengths and challenges. Activities were designed around participants’ responses. For example, several of the participants stated that they enjoyed soccer. As such, a soccer ball was provided to participants during the lunch hour to allow for enjoyable physical activity. Based on responses, it was also found that many of the participants were anxious in new social situations. For this reason, and to allow program staff to get to know the participants, a pre-program meet and greet was implemented. This element of the program received positive feedback from parents and participants and was helpful to the program staff. For similar programs, it is highly recommended to include an informal meet-up prior to the start of the program. Consider the following parent quote:

“Honestly, I think this program was perfect as is and I think it was great that there was a meet and greet in the beginning so the kids could get familiar with each other and the [program staff].”

- **Flexibility-** Flexibility must be incorporated into all plans related to this type of program. Participants must be given choice. This is the main factor in differentiating between the program and a school setting. By listening to the participants and taking their suggestions into account, they began to trust the staff and feel more comfortable sharing.
- **Team building-** Team building was emphasized through creative problem-solving challenges. This allowed participants to learn about their strengths while building relationships with other participants. These activities provided opportunities for mentors to engage in informal dialogues with participants about how divergent thinking can be applied in an engineering setting. These discussions are a key opportunity for program staff to discuss student strengths and encourage creative solutions to problems. In one particular moment, a conversation between a participant and the program manager about bridge materials affirmed the creative problem-solving abilities of the participant. The participant expressed that she might consider “switching to engineering.” This was later confirmed through parent feedback after the program:

“[She] has always said she wanted to go into a career with animals but after this program she shared with me also that she is rethinking to possibly try engineering.”

- **Esteem building-** ADHD Roundtables and informal conversations throughout the week emphasize the strengths of students with ADHD.

“He really loved the program! He was sad when it was over which is a huge testament to how he felt about it. As you know, he was very nervous in the beginning, but you all made him feel much better and as he opened up he felt better each day.”

Discussion

While both pilots were successful, several criteria should be considered prior to implementing a similar program. Challenges faced and suggestions for future deliveries will be discussed to inform the development of future programs. The main challenge in both programs was recruitment of students. For both the high school and middle school offerings, program staff reached out to local school administrations and guidance counselors to disseminate information on the program. Two of the biggest barriers to recruitment are 1) concerns about student privacy, and 2) concerns for the wellbeing of participants. Typically, participation in a summer program or camp does not carry a risk to the privacy of the participant. However, when a program is developed for a particularly vulnerable population of students, i.e. students with a diagnosis that is considered a disability, a deficiency, and a disorder, participation in the program carries the risk that the participant’s diagnosis may be revealed to others, simply from their participation. By the time students with ADHD are in middle school, they are well aware of the stigma associated with their diagnosis. Many students at this age have already encountered significant negative attitudes about ADHD through their educational experiences and may choose to not share their diagnosis with others. Furthermore, because the program is aimed at minors, all recruitment efforts must pass through parents, guardians, school counselors, or other responsible adults. Adults who are aware of students’ diagnoses, especially in the case of school personnel, take extreme care to maintain the privacy of students. Parents may choose to not disclose their child’s diagnosis to avoid the stigma of the disability label.

In addition to concerns about privacy, parents, teachers, counselors, and psychologists must safeguard children from potential harm. Out of an abundance of caution, many adults in these roles may decline to share recruitment flyers for the pilot program because it was not well established. For potential participants in a pilot program, there is a risk that the program may not be well planned or even that despite the best intentions of staff, the program may cause harm to participants. To this end, the most successful recruitment strategy for the programs was word of mouth. One example of this was someone with direct knowledge of the program (for example, an employee in the civil and engineering department) sharing the program details with those they know (friends and family). It is anticipated that this was most successful as there was a personal endorsement of the program from someone the parents trusted.

In addition to challenges with recruitment, there are considerations for program staff. It is critical for all staff to have an in-depth understanding of the challenges related to ADHD. This includes providing mentors with first-hand experience. All staff and mentors must be well-versed in, and deeply committed to, a strength-based model for students with ADHD. All involved adults must be trained so that they understand how to create an environment that allows students

with ADHD to thrive. We discourage efforts to expand or duplicate this program without the inclusion of a carefully selected team of program staff and mentors. This makes scaling the program more challenging due to limited training resources. Finally, it is important to note that the success of such a program is dependent on a supportive environment. In particular, departmental leadership must be aware of the program and supportive of its goals.

Conclusions

Delivery of the high school and middle school programs were critical in understanding how pre-college students would respond to a strength-based engineering experience. Major findings from the program director and staff are listed below:

- Strength-based programs are critical in building the self-confidence of participants. A program that does not discuss disabilities, or only focuses on coping strategies does not define it as strength-based. To be able to implement a strength-based program, it is critical that all personnel involved have a thorough understanding of the participant group and believe in the mission of the program.
- Students with ADHD at all grade levels benefit from a personalized learning environment that is centered around student interests and features flexibility and choice. Allowing students to learn in a way that is more consistent with their strengths and interest can lead to improved performance.
- Interactions with role models and mentors with ADHD in the context of engineering can encourage students to consider engineering as a career path. In addition, interactions between peers and roundtable discussions can help build relationships and normalize the diagnosis. Several students noted similar struggles in traditional environments and discussing these struggles during roundtable discussions led to a feeling of belonging.
- A comparison of the performance of the middle and high school programs indicates that the age in which the students were introduced to a strength-based perspective toward ADHD was critical in shaping the participants' perceived belief in their engineering abilities.

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