Board 155: Broadening Participation and the Mission of Engineering for US All (e4usa) through Design Projects That Engage Students with Disabilities as Stakeholders (Work in Progress)

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Abstract

Students with disabilities (SWDs) and neurodiverse students are underrepresented at all points along the educational pathway in engineering. One potential entry point for engaging SWDs and broadening future participation in engineering is through the role of stakeholder in engineering design challenges, and specifically during high school, which is a crucial part of the pathway to engineering. High school teachers and students engaged in Engineering for US All (e4usa) have completed several engineering design projects involving SWDs as stakeholders. These projects represent a human-centered approach to engineering that emphasizes a comprehensive understanding of stakeholders.

This work in progress will present results from surveys completed by e4usa teachers and students who have engaged in disability-centered engineering design challenges, with SWDs serving as the stakeholder to understand their experiences. Additionally, SWDs serving as stakeholders and those that support them (e.g., special education teachers, paraprofessionals, related service providers, families) will be interviewed about their experiences engaging in their project. Potential implications of the research findings include the impact of engaging SWDs in engineering design, especially as it relates to increased knowledge of general education teachers and students about inclusive practices and supports (e.g., evidence-based practices, alternative communication strategies, prompting). Additionally, the outcomes may contribute to efforts to broaden the participation of SWDs in engineering. Doing so, will help support the e4usa mission, which aims to demystify and democratize the learning and practice of engineering by increasing engineering literacy for all and expand opportunities for those traditionally underserved and marginalized in engineering to pursue careers as engineers and expand the STEM workforce pipeline.

Introduction

The societal role of engineers has steadily evolved from a technical problem solver to that of a "technical mediator," in which engineers engage with stakeholders to define the problem, ideate, and develop solutions [1,2]. Yet, engineering curricula still tends to focus on guiding students through problems that can be answered in a single, technical solution [3], ignoring the complexities needed to prepare students to solve real world problems [3, 4]. As stated by Schwartz et al. [2], "of particular interest to educators are strategies for incorporating community engagement as early as the problem definition stage of an engineering design project." One avenue for incorporating early engagement in engineering design projects is through the introduction of human-centered design, a process in which design decisions are informed through a comprehensive understanding of the stakeholders [5].

High school is a critical part in the pathway to engineering [6]. One potential entry point for recruiting students into the engineering pathways is through stakeholder engagement in engineering design challenges. Engaging with stakeholders allows students to not only engage in hands-on learning, but also helps build relevancy and ownership in one's project, which has

shown to garner pre-college engineering education engagement and interest [7]. Access to and engagement with pre-college engineering education helps to develop students' engineering skills that will enable them to participate and make informed decisions in the world [8]. Regardless of one's future career path, the engineering mindset teaches students important skills applicable to almost every field, such as critical thinking, technical literacy and problem-solving skills [9-11].

Engineering for US All (e4usa) aims to demystify and democratize the learning and practice of engineering by increasing engineering literacy for *all* and expanding opportunities for those traditionally underserved and marginalized in engineering to pursue careers as engineers and expand the STEM workforce pipeline. The work in progress paper presents the engineering design projects from e4usa that closely engaged students with disabilities (SWDs) as the stakeholders, and specifically focuses on the observations and experiences of e4usa teachers, e4usa student teams, and the SWDs who served as the stakeholders and the educators that support them (e.g., special education teachers, paraprofessionals, speech-language pathologists, occupational therapists, families).

e4usa Curriculum

The e4usa curriculum focuses on four main areas (or threads): Connect with Engineering, exploring engineering identity and an exploration of 'engineering' as a verb and a noun; Engineering Professional Skills, exploring written and verbal communication, project management, and teaming; Engineering in Society, exploring the implication of engineering solutions on environmental, ethical, and social aspects of society; and Engineering Design, featuring an engineering design process. Each engineering design follows an engineering design process, including evaluation based on stakeholder analysis. The curriculum is designed to be offered as a yearlong high school course. It consists of eight units, designed with the idea of spiraling complexity. Concepts are introduced and are reinforced through later lessons and activities, allowing increasing autonomy and creativity throughout the course. The first two units focus on a true introduction to engineering, including social, ethical, and environmental ramifications of engineering design, and engineering identity. Beyond the introductory units, students experience (up to) three complete engineering design experiences. Units 3 and 4 walk student teams through a project designing a solution for a challenge identified by the class. It is expected that this design is the students' first time designing an engineering solution. After this initial experience, teachers typically choose a path through either units 5 and 6 or unit 7. Units 5 and 6 have more built-in structure for the teacher, and empower students to design a solution to a problem on a much broader community/global scale, typically for an external client, working with a stakeholder in their community. Unit 7 asks students to identify a problem for which they have a personal interest; thus, each team may be designing toward a solution that is quite different from other teams in the class [12].

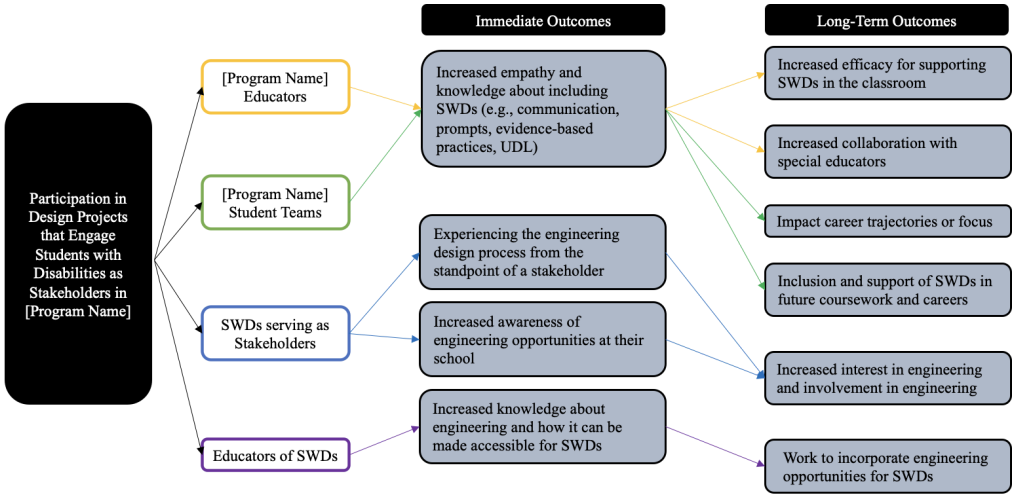
Within the curriculum, a stakeholder is defined as a party that has an interest in the solution to the problem, especially one whom the students can contact with questions or potential ideas. e4usa Students are encouraged to consider multiple stakeholders, including individuals and groups who are directly and indirectly responsible for or are affected by an engineering problem or design. Whether the project is a local, perhaps school-based design or a community-based design, stakeholders are identified, criteria and constraints are defined from their perspective, and they are asked to evaluate the design at crucial stages.

Purpose

The work in progress paper presents the engineering design projects from e4usa that engaged SWDs as the stakeholders, and specifically focuses on the observations and experiences of e4usa teachers, e4usa student teams, and the SWDs who served as the stakeholders and the educators that support them. The logic model in Figure 1 further presents the desired outcomes of educators and students participating in design projects that engage SWDs. As mentioned, the mission of e4usa is to increase engineering literacy for *all* and expand opportunities for those traditionally underserved and marginalized in engineering. Showcasing these unique engineering design projects may help increase interest in engineering by all students, including those with disabilities, as well as increase the knowledge and empathy of high school engineering teachers and students about practices and supports (e.g., evidence-based practices, alternative communication strategies) that can lead to increased understanding and inclusion of the disability community in engineering classrooms and in other contexts. This closely aligns to the importance of engineering being human-centered and the four threads of the e4usa curriculum.

Figure 1.

Logic Model



The research aims to address the following questions:

1. How were teachers impacted as they observed and supported student teams using the engineering design process to design a solution for a SWD serving as a stakeholder?
2. What did student teams experience and how did they remain responsive to the SWD serving as a stakeholder as they were designing a solution?
3. What did SWDs serving as stakeholders experience as they were working with a student team?

4. Following the experience, did SWDs and the educators supporting them change their perspectives on engineering?

5. Does participation as a stakeholder influence SWDs' future interest and engagement in engineering?

Methodology and Analytic Approach

Participants

Participants included e4usa teachers and students who have engaged in disability-centered engineering design challenges, with SWDs serving as the stakeholder to understand their experiences. Additionally, SWDs serving as stakeholders and those that support them will be included. This work in progress paper describes the initial results from surveys of teachers. The teachers who responded regarding their experience in supporting these projects range in experience from two to four years teaching in e4usa.

Data Collection and Analysis

Preliminary data was collected from e4usa teachers via a survey (see Table 1). Of the approximately 60 teachers who received the survey, 8 responded that they had supported students with an engineering project in which SWDs served as stakeholders.

Table 1

Survey Questions for e4usa Teachers

1. Explain the project(s) and how your e4usa students used the engineering design process to design a solution for a student with a disability serving as a stakeholder.
2. How did observing your e4usa students work with students with disabilities as stakeholders make an impact on you?
3. What lessons or activities did you refer back to or had the most impact when supporting team(s) working with students with disabilities serving as stakeholders?

Data will be collected from the remaining groups at a later date. However, the questions to be asked are detailed in Table 2 and Table 3. The preliminary data and additional data to be gathered will be analyzed using inductive coding and the constant comparative method in order to identify emergent themes that address the above listed research questions.

Table 2

Survey Questions for e4usa Student Teams

1. Explain the project and how you used the engineering design process to design a solution for the student with a disability serving as a stakeholder.
2. How has working with students with disabilities as stakeholders made an impact on you?
3. How did you adjust your approach to communication, thinking about the solution, etc?
4. How did working directly with the student with a disability serving as a stakeholder impact your design solution?
5. What did you learn about designing products for students with disabilities after this experience?
6. Did this experience lead you to learn more about individuals with disabilities? Has it made an impact on your career trajectories?
7. What lessons or activities did you refer back to or had the most impact when working with students with disabilities serving as stakeholders?

Table 3

Survey Questions for Stakeholders, Including Students with Disabilities and Educators

1. What was your experience working with the e4usa student team to design a solution?
2. How did the e4usa student team go about gathering information about what was needed to design the solution?
3. As a student, have the experiences led you to become more interested in engineering?
4. Were there any specific aspects of the final design solution that changed as a result of an initial or prior conversation you had and/or feedback you provided to the e4usa student team?
5. Did engaging in this process change the way you viewed engineers or the engineering process?
6. As an educator or service provider, did the experience change your perspectives on engineering and its integration into classrooms serving students with disabilities?

Results

The initial results from e4usa teachers indicates that there is a wide variety of engineering design projects undertaken by student teams in the program to support SWDs within their school or community. Table 4 provides details on a variety of projects.

Table 4

Descriptions of Engineering Design Projects

Teacher[1]	Brief Project Description
Blake	Safe and adaptive swing for an older child with a disability
	Adaptive tricycle which includes a redesigned mount system for a push bar, remote braking system, supports for holding the handlebars, and modified pedal system for a young man with disabilities in the community
Benjamin	Crutch supports to prevent trip hazards and minimize the need to pick them up from the floor
Calvin	Protective guard to protect student's hands from getting caught within the wheel spokes of the wheelchair
Dean	Support system to teach new hockey players with developmental disabilities to ice skate
Hayley	Knob to increase accessibility to a sink for a preschool student with Williams Syndrome
Jack	A number of projects to support autism life skills classrooms, which included adaptive writing tools, eating utensil tools, footrest design, fortified cabinet safety lock, and keyguard for an augmentative and alternative communication (AAC) device
Katherine	Fidget tools to help SWDs remain focused during instructional time

[1] Pseudonyms are used for all teachers

When describing how supporting these projects impacted them, the teachers emphasized that they had a meaningful impact on them as educators and on the student teams designing the solutions to these disability-centered engineering design challenges. Jack shared that the projects that involved SWDs as stakeholders highlighted an "underrepresented facet of engineering as a service profession." For Calvin and Benjamin the project showcased how much the engineering students were conscientious of their stakeholders and striving to help others. For Katherine, she was proud of how well e4usa students worked with SWDs to develop a variety of fidget tools to increase their focus. When describing the adapted tricycle his students designed, Blake shared, "It is incredibly intrinsically rewarding to see my students take a strong interest in meeting the needs of this young man." Hayley stated that these projects enabled the students to be "invested in doing something for the greater good, not just for a grade." Similarly, Benjamin's students shifted their focus from grades to the solution and iterated upon the prototype to build a better product based on feedback from the stakeholder.

In describing how the e4usa curriculum supported this work in designing solutions for SWDs, most teachers referred to several specific lessons in the course. These lessons centered on the themes that engineering is creative, engineering is human-centered, and engineering is

responsive. Teachers specifically referred to content that discussed engineering empathy, teamwork, and iteration within these lessons. Oftentimes, teachers referred to multiple lessons that were found in the early units of the curriculum. Jack also commented on additional activities that they incorporated into the course for this experience, stating "we had special education teachers present to our students about the array of disabilities, adaptations, etc. - essentially a primer to the special education classroom. We then moved into examining a list of existing problems for potential projects." Having student teams meet with stakeholders with disabilities and work to understand constraints and criteria was also key for Blake, Dean, and Katherine. Time spent empathizing and understanding SWDs had an immense impact on the prototypes and final solutions developed.

Discussion and Implications

These results indicate that the e4usa curriculum provides specific supports that empower both students and teachers to engage SWDs as stakeholders in engineering design projects, as well as provides flexibility to add in additional topics to enhance the design process through increased information from stakeholders with disabilities and other experts. The main threads addressed by the teachers when supporting these projects included Engineering in Society, Engineering Professional Skills, and Engineering Design. These threads represent both technical aspects of engineering alongside aspects of being an engineering professional (e.g., communication, project management), and emphasizes how engineering and the designing of solutions impacts society.

Potential implications of the research findings include increased knowledge of general education teachers and students about inclusive practices and supports, and influencing students' engineering career trajectories. Future data collection may further reveal that both e4usa teachers and students have increased their empathy towards SWDs and increasingly see engineering as being human-centered and that a comprehensive understanding of stakeholders is pivotal in designing solutions [5].

Additionally, the outcomes may contribute to efforts to broaden the participation of SWDs in engineering coursework and careers. Pre-college learning environments that work to intentionally include SWDs and neurodivergent populations, are crucial to broadening diversity, equity, and inclusion initiatives in engineering. This work in progress and efforts to engage SWDs first as stakeholders is just one of many initial steps to addressing how to further engage and better include the SWD and neurodivergent student populations in pre-college engineering design courses. Our future work will further explore SWDs and neurodivergent students' experiences as stakeholders in the e4usa course, which may reveal their increased interest in engaging in engineering coursework. While this work in progress only presents findings where SWDs serve as stakeholders and provide input to engineering teams, the e4usa course is presently being piloted at a school serving SWDs. Future work will showcase how the students in this classroom will work as a team to engineer solutions to help fellow SWDs at their school. It is expected that these experiences will have implications for the improved support of SWDs and neurodivergent students in both the e4usa course and other pre-college engineering courses.

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