Board 154: Broadening Participation and the Mission of Engineering for US All: A Case Study of Engineering in a Classroom Serving Students with Disabilities (Work in Progress)

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Abstract

Strategic Goal 1 of the NSF 2022-2026 Strategic Plan aims to broaden the participation of the "Missing Millions" or under-served, underrepresented, and marginalized populations to fully participate in STEM. Students with disabilities represent one of these marginalized groups. In response to this NSF priority, Engineering for US All (e4usa) democratizes access to engineering knowledge and practices, especially for students from underrepresented groups and areas with limited access to engineering education. The curriculum developed by e4usa includes hands-on engineering projects and is designed to be engaging and relevant to real-world problems. Furthermore, it seeks to promote not only technical knowledge and skills but also creativity, critical thinking, collaboration, and communication skills essential in the engineering profession. Through these efforts, e4usa is broadening participation in engineering professions and promoting a diverse engineering workforce that can address the various challenges faced by society. This work in progress presents a case study of a high school special education teacher implementing the e4usa curriculum for students with disabilities. The work in progress paper will present the intentional modifications and supplements to the curriculum that aided in the removal of barriers and increased access to and success in engineering education for students with disabilities in the classroom.

Broadening Participation and the Mission of Engineering for US All: A Case Study of Engineering in a Classroom Serving Students with Disabilities (Work in Progress)

Many education institutions lack adequate staff training and planning processes to effectively cater to the learning requirements of students with disabilities (SWDs) (Anderson et al., 2022; Figard et al., 2023). A viable solution involves providing targeted professional development opportunities to faculty and staff. Special education training programs have proven to enhance faculty attitudes, knowledge, and skills in supporting students with disabilities (Dignath et al., 2022). It is crucial to extend these training initiatives to encompass the school's administration and staff (Hester et al., 2020; Walker, 2016). The establishment of an academic culture that prioritizes inclusion plays a pivotal role in shaping the attitudes and support services provided by faculty, staff, and administrators for students with disabilities (Theoharis et al., 2020).

This work in progress paper presents a case study of a special education teacher who teaches the Engineering for US All (e4usa) curriculum to SWDs. In this case study, we detail the intentionality in the teacher's pedagogical practices and curricular adaptations to teach the e4usa course to SWDs. The understanding of these practices will help to support other engineering educators with the shared goal of broadening participation in engineering. The research questions for this study include:

1. How does a special education teacher practice differentiation, and provide accommodations and modifications when teaching thee4usa curriculum to support SWDs?
2. How do these pedagogical strategies lead to removing barriers SWDs may experience in engineering education?

e4usa Overview

e4usa democratizes and demystifies engineering for all by introducing engineering knowledge and design principles to a new generation of students. e4usa invites all schools, teachers, and students to participate fully, regardless of their technical background or preparation. By doing this, e4usa aims to broaden participation in engineering professions and promote a diverse engineering workforce that can address the various challenges faced by society. The curriculum developed by e4usa includes hands-on engineering projects, and it is designed to be engaging and relevant to real-world problems. Furthermore, it seeks to promote not only technical knowledge and skills but also creativity, critical thinking, collaboration, and communication skills essential in the engineering profession (Figard et al., 2022). The e4usa curriculum consists of a series of thematically designed units that progressively build students' understanding and skills in engineering. The curriculum is intricately woven with four thematic 'threads' that guide students through the multifaceted world of engineering (Reid et al., 2020). The Red Thread: Connecting with Engineering aims to evolve the understanding of what engineering entails and what it means to be an engineer. The Yellow Thread: Engineering in Society explores the broader impact of engineering on society by analyzing past engineering successes and failures and their societal impacts. The Blue Thread: Engineering Professional Skills centers on developing essential professional skills for engineers, including effective team collaboration strategies, diverse forms of communication tailored to different audiences, and project management. Finally, the Green Thread: Engineering Design delves into the entire engineering design process.

Methodology

Study Design

A single case study approach was undertaken to explore the research questions. Case studies examine novel and intricate situations in an integrated manner, which can reveal existing problems and identify potential solutions to these problems (Baxter, & Jack, 2008; Creswell, 2014; Yin, 2008). Case studies have been increasingly used in instruction and in special education to expand educators' knowledge, perspectives, and critical thinking skills (e.g., Holmes, 2021; Morris, 2021). Insights gained from case study research support the understanding of special education interventions and are crucial for developing effective educational programs for SWDs (Nilholm, 2021).

Research specifically on how engineering education can be made more accessible to SWDs is limited (Ehsan et al., 2018; Kouo et al., 2021). This case study on Mr. Richard Deanne Sagun's efforts to intentionally provide SWDs access to engineering can provide insights to other educators to improve the quality of engineering education for SWDs and potentially all students. Mr. Sagun is also a co-author, which influences the positionality of all authors, as described in further detail below. The data explored within this case study included observations of the classroom teacher while teaching the e4usa curriculum, instructional materials, and reflections following instruction. Engaging in this case study

enriches the understanding of engineering pedagogy and supports the practices of other educators aiming to remove barriers and support SWDs in engineering education.

Teacher Selection and School Site and

The case study took place at a school that provides extensive educational and support services to children and adolescents who have autism, trauma disorder, and multiple disabilities. It is also one of the e4usa partner high schools that offer a pre-college engineering program to SWDs. Mr. Sagun oversees the school's engineering program. Mr. Sagun has taught high school biology and physics for the past 14 years, and taught in the Philippines prior to becoming a cultural exchange teacher in the United States. He holds a bachelor's degree in secondary education with a specialization in physical sciences and a master's degree in biology education. Additionally, Mr. Sagun has certification as a special educator, and also holds certification in professional crisis management, making him qualified to address students' behavior-related concerns in a classroom setting. Mr. Sagun has completed the e4usa New Teacher Summer Professional Development and continues to engage in continual professional learning opportunities with e4usa.

Mr. Sagun's special education classroom is designed to meet various learning needs, featuring learning stations for independent work, teacher-led instruction, and hands-on engineering activities. It includes visual aids like class schedules and engineering posters, sensory tools (e.g., fidgets, headphones, wobble cushions), and technology (e.g., Chromebooks) to aid learning and comfort. A Teacher Assistant provides extra support for students with disabilities, ensuring a personalized and inclusive educational experience.

School Population and Student Achievement

During the 2021-2022 academic year, the school enrolled a total of 125 students in the primary school, middle school, and high school programs. The e4usa engineering course is offered in the high school program which is integrated with the 12th grade science course. The high school program is divided into two tracks: a.) High School Diploma Track and b) Career Readiness Certificate Track. The students in the Diploma Track are working towards earning a High School Diploma. The Career Readiness Track consists of students aged 14-21 who are working toward earning a High School Certificate of Program Completion. There are three students enrolled in 12th-grade science. Considering their primary disabilities, two of the students have autism while one student has multiple disabilities. Additional information about the students is presented in Table 1.

Table 1. Learners' Profile

Student	Age	High School Track	Profile
Ava	18	Diploma Track	● Her interests include reading, music, and computers. ● Challenges in the classroom involve a "quiet refusal" and verbal repetition.
Kiernan	21	Career Readiness Track	● She completes tasks when given clear instructions and modeling. ● Performs significantly below her peers in reading, writing, and math.
Matt	18	Diploma Track	● He excels in classroom activities, blogging, and creating YouTube content. ● Challenges in reasoning, working memory, and social skills impact his learning progress.

Data Collection

Yin (2003) suggests that multiple sources of data should be collected for case studies, which can support the triangulation of evidence or the credibility of the data gathered. A variety of data sources were collected in the study during the 2021-2022 academic year.

Observations and Instructional Materials

The primary data source included remote observations of Mr. Sagun's instruction of e4usa lessons. The observations were conducted with the support of a microphone and a camera positioned near the ceiling at the front of the classroom, which provided an aerial view of the entire classroom. Due to the positioning of the microphone in the classroom, it is important to note that there were periodic issues with capturing both teacher and student voices depending on their distance from the microphone. Observations were approximately one hour long and were conducted by the first and second authors. An

observation protocol was utilized. For this work in progress and the identified research questions, the authors focused specifically on modes of instruction, materials or tools used in the lesson, a summary of the content, teacher interaction or engagement with students, and the use of assessment tools. Additional detail on the observed lessons is presented in a subsequent section. In addition to observations of Mr. Sagun's instruction, instructional materials were collected. These included PowerPoint slides, worksheets, and other materials used to teach the lessons.

Post-Observation Form

When possible, Mr. Sagun completed a post-observation form. The form included the following questions: (1) What were your goals for today's class session?; (2) Did you use any resources outside of the e4usa curriculum in preparation for the class session?; (3) How confident and prepared did you feel before teaching the lesson?; (4) How did you feel the lesson went?; and (5) What, if any, changes might you make if teaching the class session again?

e4usa Lessons

This study analyzes observations of Mr. Sagun's instruction of specific lessons from Units 1 and 2 of the e4usa curriculum. For this paper, Lessons 1 and 7 from Unit 1 and Lessons 1, 4, 6, and 7 from Unit 2 were examined. These lessons emphasize the importance of engineering communication methods and the continuous evolution of the definition of engineering and an engineer's role. They also highlight collaboration within teams, addressing ethical considerations, understanding the broader applications of engineering, and tackling societal challenges. A full description of the lessons, along with their subsequent learning outcomes and thread connections are detailed in Table 1.

Table 1

Overview of Analyzed Lessons from Units 1 and 2

Unit and Lesson Number	Name of Lesson	Description of Lesson	Learning Outcomes	Thread Connection
Unit 1, Lesson 1	Career Relationship with Engineering	This lesson introduces students to the breadth of engineering and its impact on everyday life and society.	Use various engineering communication methods; Iterate and evolve the definition of what it means to engineer and be an engineer	Red, Blue
Unit 1, Lesson 7	Introduction to Engineering Ethics	This lesson introduces students to engineering ethics. Students learn about safe drinking water as a global issue and explore solutions related to clean and safe drinking water.	Iterate and evolve the definition of what it means to engineer and be an engineer; Learn about the value of engineering within all careers; Understand and apply ethical considerations when exploring an engineering problem; Investigate societal challenges and the role that engineering plays in solving these challenges; Identify and analyze issues when bringing a solution to scale	Red, Yellow
Unit 2, Lesson 1	Introduction to Teaming	This lesson introduces students to the characteristics of effective teamwork. Students apply these concepts through a teamwork skill-building activity.	Collaborate effectively in a team	Blue
Unit 2, Lesson 4	Problem Definition	This lesson introduces students to problem definition and evaluation during the design process. Students learn to consider design criteria, specifications, and constraints during problem definition.	Collaborate effectively in a team; Identify and describe a problem that can be solved with a new product or process; Plan and conduct research by gathering relevant and credible data, facts, and information; Articulate appropriate STEM practices and principles in the design	Green, Blue
Unit 2, Lesson 6	Design Selection	This lesson helps students practice design selection through the development of selection criteria and a scoring system.	Collaborate effectively in a team; Articulate appropriate STEM practices and principles in the design; Evaluate solution alternatives and select a final design by considering assumptions, trade-offs, criteria, and constraints	Green, Blue
Unit 2,	Sketching a	This lesson focuses on creating	Use various engineering communication	Blue

Lesson 7	Design	sketches that include dimensions. Students learn how to make two- and three-dimensional drawings by hand and by using computer software.	methods

Data Analysis

Qualitative analysis of the data source was supported by Dedoose, a qualitative data analysis platform. Using inductive coding to identify emergent themes, the authors thoroughly immersed themselves in all of the data sources (Saldaña, 2011). Guided by the research questions, the authors independently coded the data using keywords or phrases to represent important or interesting observations (Bogdan & Biklen, 2007; Corbin & Strauss, 2015; Seidman, 2013). This process led to a codebook with 12 codes divided into 5 categories. The validity of the findings was supported by the recurrence of codes. Member checking occurred throughout the analysis process by engaging the case study teacher. The first author verified interpretations of the data sources and the final themes were shared with the case study teacher to provide him with another opportunity to deliver feedback. Providing further credibility, this manuscript is co-authored with the case study teacher.

Positionality Statement

The authors of this article include a subset of the overall e4usa team who engage in research and dissemination. An educator of e4usa is also a co-author and the focus of the case study. Core to the e4usa mission is the nationwide expansion of student and teacher access to engineering, with intentional efforts to reach populations traditionally underrepresented in the field. The authors have a shared and invested interest in the success and impact of e4usa. The authors are particularly dedicated to ensuring that engineering education is inclusive of all students, including SWDs.

Results

The analysis resulted in 5 major themes that centered on preparing students' prior to beginning the lesson, strategically integrating IEP goals and objectives, applying the Universal Design for Learning (UDL) framework during instruction, utilizing a variety of instructional materials, and engaging in teacher reflection.

Preparing Students for Learning

Prior to the start of each lesson, Mr. Sagun was observed building rapport with the students. This included discussing with students about their weekend and what they were looking forward to that day. Continually connecting with students allowed Mr. Sagun to incorporate their interests and activities in the lessons and connect it to engineering.

In addition to building rapport with students, Mr. Sagun began each lesson with a mindfulness activity. The investment of approximately 2 minutes involved a video-guided meditation. In Lesson 2.1, Mr. Sagun even asked students to identify their current emotions, with some students sharing that they were tired or calm. The mindfulness activities provided a moment for students to reset and refocus, and supported student engagement in the lessons.

Embedding IEP Goals and Objectives

With intention, Mr. Sagun ensured that the lessons also supported students' IEP goals and objectives and led to opportunities to collect progress monitoring data. For example, in Lesson 2.1 Mr. Sagun was able to gather data on students' fine motor skills as they created a rain shelter. In each of the observed lessons, Mr. Sagun also asked students to read text from presentation slides out loud to support students' verbal reading and comprehension goals. Written expression goals were targeted, especially in Lesson 1.7 where students practiced writing an argumentative essay about whether ethical issues were at play in an example of an engineering design solution shared in class. Addressing IEP goals and objectives of each student during the lessons is critical for students with disabilities to make progress in areas of need and have multiple opportunities to practice skills.

Providing Multiple Means of Engagement and Action and Expression

Applying the UDL framework, Mr. Sagun utilized strategies to ensure students were engaged. Students' connections to the activities in the e4usa curriculum were vital. In Lesson 1.1, Mr. Sagun worked to help students connect their future career aspirations with engineering. These conversations supported students in realizing that 'engineering is everywhere' and helped them envision themselves as engineers.

Mr. Sagun used probing questions, such as asking for clarification from students, in all of the observed lessons. Specifically, in Lesson 1. 7 Mr. Sagun challenged students to further reflect and discuss the importance of failure and iteration in engineering. In Lesson 2.1, Mr. Sagun probed students about whether the rain shelter they built met their established design criteria.

Students were further engaged in the lessons by working collaboratively with their peers. In Lesson 2.1, students worked as a team to build their rain shelter. Mr. Sagun supported on-task behavior by circulating the classroom and providing gentle reminders to individual students, and facilitated reflective discussions about their teaming skills with the support of a teamwork rating scale.

Further application of UDL was observed when Mr. Sagun encouraged students to showcase their learning through discussions, reflections, scaffolded worksheets, and responses with post-it notes. This gave students the autonomy to identify their preferred method of demonstrating their understanding.

Variety of Instructional Materials

Written expression can be challenging for students with disabilities. In Lesson 1.7 Mr. Sagun provided a scaffolded worksheet to guide students' argumentative essays. As noted earlier, this supported students' IEP goals and objectives. Metacards support students' cognition and retention of information, and often include visuals. Mr. Sagun used metacards in Lesson 1.1 to support students' understanding of engineering careers and their impact on everyday life and society. In Lesson 1.1, Mr. Sagun utilized WebQuest, an inquiry-oriented lesson format leveraging the internet, to support the investigation of engineering. Using WebQuest, students were able to understand how different engineering careers impact everyday life. These observations highlighted how Mr. Sagun used a variety of instructional materials to support and engage students.

Teacher Reflection

Mr. Sagun continually engaged in reflections on his instructional practices. Reflections, especially through the post-observation form, supported Mr. Sagun's future planning. Mr. Sagun frequently reflected on aspects of the lessons that went well and should continue, as well as opportunities for improvement. These opportunities included the provision of different materials and additional time for students to work collaboratively in teams and communicate with one another.

Discussion

As a special educator, Mr. Sagun made student-centered decisions in the planning and implementation of e4usa lessons. Many of these instructional practices and adaptations to lesson materials were complementary. For example, the building of rapport with students, mindfulness activities, and helping students connect to the instructional content and probing questions, supported students' engagement. These strategies, along with efforts to ensure progress towards students' IEP goals and objectives removed barriers and helped students with disabilities connect to engineering as a field and engage in the engineering design process.

With the mission of democratizing and demystifying engineering for all learners, e4usa educators continually work to help students with disabilities access engineering education. Proactive, student-centered instructional decisions help students with disabilities not only engage in the engineering design process but also make meaningful progress toward IEP goals and objectives. Educators with aligning goals of broadening access to engineering can apply these practices to remove barriers for their students with disabilities.

Future steps for this research will involve directly connecting Mr. Sagun's instructional practices with the recently revised 2nd Edition of the Council for Exceptional Children High-Leverage Practices for Students with Disabilities (Aceves & Kennedy, 2024). Reporting on these alignments will further highlight the importance of Mr. Sagun's instructional practices in teaching the e4usa curriculum and may also shed light on other practices, including evidence-based practices, that can specifically be leveraged to broaden access and participation in engineering education.

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