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Tugba Boz
Purdue University, United States

Rebekah Hammack
Purdue University, United States

Nicholas Lux
Montana State University, United States

Paul Gannon
Montana State University, United States

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Abstract

Indigenous populations, constituting 6.2% of the global population, face challenges in STEM education due to systemic barriers and limited exposure to science and engineering. Our research, part of a federally funded project, aimed to address these challenges by implementing Community-Based Engineering (CBE) education in an elementary school located on a Native American Reservation in the United States. In this paper, we used CBE as our theoretical framework situating engineering within the context of students' communities and cultures. Our participants included 15 students and two Native American teachers with varying teaching experience. We employed mixed methods and combined quantitative tools such as the Engineering Identity Development Scale and the Engineering & Technology subscale of the S-STEM survey, with qualitative data from teacher and student interviews. Our analysis revealed significant changes in students' perceptions of engineering for their communities and their personal engineering identities after they engaged with CBE lessons. We also found that the cultural connections to community were evident in student interviews. Furthermore, teachers appreciated CBE and emphasized that these engineering lessons enrich their rich traditions and practices. This study highlights the effectiveness of CBE and demonstrates how engineering education can be more inclusive and resonant with Indigenous students.

Introduction

Indigenous people constitute 6.2 percent of the world's population and commonly have a historic connection with their lands (United Nations, 2023). This connection is deep and forms a vital part of the Indigenous populations' identity although they have faced the harsh reality of being displaced from their ancestral lands over time. Additionally, Indigenous people globally confront numerous other challenges, including limited access to social services and the denial of their rights to live according to their own values, needs, and goals (United Nations, 2023).

In the context of the United States, these challenges are exacerbated in the areas of STEM education and careers. Indigenous groups and other minorities face significant barriers that disproportionately hinder their pursuit of careers in STEM fields (Fry et al., 2021). The difficulties often begin early, even before individuals from systematically marginalized groups enter the workforce or higher education (National Academies of Sciences, Engineering, and Medicine, 2023). A notable gap in exposure to science and engineering at the elementary school level is more visible among schools and school districts serving minoritized students (National Academies of Sciences, Engineering, and Medicine, 2022).

The limited exposure and access to quality engineering practices among Indigenous students necessitates the development of accessible science and engineering education opportunities (National Science Foundation, 2021). This approach should move beyond traditionally privileged white, middle-class perspectives in STEM fields and include Indigenous ways of knowing and epistemologies with a particular focus on place. As captured by Barnhardt and Kawagley (2005, p.11), "Indigenous people have traditionally acquired their knowledge through direct experience in the natural world" unlike Western ways of knowing and epistemologies which are often based on "compartmentalized knowledge that is often decontextualized."

Moreover, as Kassam et al. (2017, p. 100) highlighted, humanity faces wicked problems that "demand engagement with cultural systems, social and institutional structures, and individual actions, all within the ecological context where they manifest themselves." Therefore, it is important to recognize that science and engineering, as disciplines, will surely benefit from the participation of individuals from a wide range of identities and cultural systems (Kassam et al., 2017; National Academies of Sciences, Engineering, and Medicine, 2022). In this paper, we seek to reveal the transformative potential of incorporating community and place-based engineering education into elementary schools serving Indigenous students, which aim not only to increase Indigenous students' interest in STEM, and in particular engineering, but also to bring a wealth of diverse insights and approaches to the STEM fields as more Indigenous students enter the STEM workforce in the future. In doing so, we report on a federally funded research project that aimed at increasing awareness and interest in engineering and engineering-related careers among rural and Indigenous elementary students aged 8-11 years by examining the following research questions:

(a) Does engagement with community-based engineering lessons result in any significant changes in Indigenous students' perceptions and attitudes toward engineering?

(b) How do students experience community-based engineering lessons? What promises and needs arise in learning community-based engineering?

(c) How do teachers experience community-based engineering lessons? What promises and needs arise in the co-implementation of community-based engineering lessons?

Theoretical Framework

Our theoretical framework is grounded in the understanding that engineering is a multifaceted discipline not only related to science and technology but also deeply embedded in social contexts. In elementary education, it is crucial to foster learning environments that enable students to connect engineering principles and practices with their social contexts and local communities. The extensive literature proposes that focusing on community-based engineering education can be a valuable approach and can promote the incorporation of local knowledge and culture in engineering education in rural elementary classrooms (e.g., Barton & Tan, 2019).

Community-based Engineering Education in Rural Schools

According to Dalvi and Wendell (2015), the Community-based Engineering (CBE) approach provides a platform where students address and resolve engineering issues within their local contexts. It allows students to identify problems and needs in the community and develop tangible or computer models to address them. In our theoretical framework, we build on various educational approaches: funds of knowledge, local rural knowledge (LRK), and place-based education (PBE). Each of these concepts is presented in a mutually exclusive manner in the literature; however, in our study, they collectively inform our operational definition of CBE.

Funds of knowledge are “historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being” (Moll et al., 1992, p.133). This concept highlights that children are actively involved and observe the exchange of goods, services, and symbolic values crucial to their households' functioning (Moll & González, 1994). Thus, the funds of knowledge approach challenges deficit thinking in education and acknowledges the valuable knowledge and skills inherent in every family (Esteban-Guitart et al., 2018). It suggests teachers can enhance their students’ learning experiences by understanding their students’ households and everyday lives and connecting them to their learning. To make this connection, teachers can be trained in ethnography and visit students’ homes to integrate their families’ funds of knowledge into their teaching methods (Llopart & Esteban-Guitart, 2017). Research shows that using this approach increases student engagement and deepens their understanding of science and engineering identities (e.g., Barton et al., 2008; Mejia et al., 2014; Rincón & Rodriguez, 2021).

We draw on the Local Rural Knowledge approach in our study because the existing research on funds of knowledge primarily focuses on informing educators and researchers about adult practices and their social worlds without specifically addressing the nuances of rural education (Subero et al., 2017). Furthermore, LRK is significant as rural schools represent 28% of all U.S. public schools (National Center of Education Statistics, 2023). Avery (2013) defines LRK as student-centered, place-based knowledge aimed at connecting students to their local knowledge in rural environments. LRK is primarily used as an approach to increase rural students’ science/STEM learning outcomes (Morris et al., 2021). Additionally, rural schools face numerous challenges including population decline, poverty, insufficient funding, isolation, a high turnover of qualified STEM teachers, and limited exposure to varied STEM practices (e.g., De Mars et al., 2022; Goodpaster et al., 2018; Howley et al., 2009; Ihrig et al., 2022). These challenges deeply affect providing meaningful schooling experiences for rural students. However, rural schools have strengths that nonrural schools may not have such as strong local ties and familiarity with the community’s needs and resources. Avery and Kassam (2011) pointed out that children and youth in rural areas naturally learn science and engineering in their daily lives:

> Instances of science and engineering are normal and frequent in rural life. Whether on the farm, working with the hydraulic system of a tractor, or in the backyard tinkering with old car parts, children in rural settings acquire science and engineering skills and knowledge in the context of their daily lives.

Therefore, emphasizing the unique strengths of rural areas, Avery (2013) proposed specific strategies for integrating LRK at both student and teacher levels within schools. Avery highlighted photo-documentation as a valuable method for recording the knowledge students acquired outside school settings and ethnographic studies and youth narratives as effective means to understand student perspectives and experiences. Avery (2013) also recommended the development of teacher place-based professional development programs to support teachers to integrate LRK into their lessons and involving local communities to utilize their expertise in rural classrooms.

We also incorporate place-based and place-conscious education (PBE) in implementing CBE in rural schools. Initially, PBE was coined to describe outdoor education aimed at helping students connect to the world (Woodhouse & Knapp, 2000) and to use their local context as a lens for schooling (Theobald, 1997). The approach to PBE has since evolved, and PBE has become a practice that more closely links schooling with the local context. It is a broad and encompassing concept as it includes:

> Experiential learning, context-based learning, problem-posing education, outdoor education, environmental/ecological education, bioregional education, natural history, critical pedagogy, service learning, community-based education, Native American education—all of these approaches to education tend to include engagement with local settings (Gruenewald, 2003, p.620)

While CBE might seem similar to these approaches, we suggest that CBE goes beyond them. By integrating insights from funds of knowledge, LRK, and PBE, we recognized the two-way symbiotic nature of CBE in the sense that CBE not only builds on the community knowledge but also contributes back to the community. This reciprocal and symbiotic nature of CBE distinguishes it from the other approaches upon which we built our theoretical framework.

One approach to CBE is the Engineering for Sustainable Communities (EfSC) Framework developed by Tan et al. (2019). This framework offers a structured model for teachers to integrate community perspectives into engineering education. It encourages students and teachers to (a) define community problems from multiple perspectives, seeking community input, and (b) integrate these perspectives into design specification and optimization to meet the community's needs. Similarly, Dalvi et al. (2016) suggested a framework with four levels: (a) identifying a specific problem or community need, (b) researching and planning a solution, (c) constructing and testing a prototype, and (d) generating explanations for what works and what does not and making recommendations to the community for next steps.

Using CBE in our study, we aim to empower rural and Indigenous students and communities through providing meaningful engineering learning and teaching experiences that are seamlessly woven in their unique contexts, experiences, and knowledge. We employ CBE to support Indigenous students, teachers, schools, and communities in challenging dominant narratives by emphasizing Indigenous ways of knowing in engineering education (Greenwood, 2009; Seniuk Cicek et al., 2021). In other words, through CBE, we aim to Indigenize engineering (also suggested as "Indigineering"), which signifies "performing engineering while incorporating Indigenous virtues" (Desjarlais, 2022, p.140).

Indigenous STEM Education

The majority of Indigenous schools in the United States are located in rural areas, and this distribution is uneven across the rural landscape (De Mars et al., 2022). Burdick-Will and Logan (2017) showed in their analysis that the majority of Indigenous students attend schools in rural locations which are located outside metropolitan areas or in the most remote rural districts detached from metropolitan areas. In addition to the isolation challenges faced by rural schools, Indigenous schools also face challenges such as the preservation of Indigenous cultures and languages (De Mars et al., 2022) and lack of integration of Indigenous knowledge in standards and curriculum (Nam et al., 2013). In this context, the prevailing universal approach to STEM education, which fails to integrate Indigenous epistemologies and perspectives, places Indigenous students at a disadvantage and alienates them from learning in mainstream schools (Chiang & Lee, 2015). Additionally, according to Locke (2018), the curriculum and textbooks do not reflect the contemporary issues regarding Indigenous history and culture and "treat the subject as frozen in time" (p.16).

A quick look into the literature shows that the majority of studies in STEM education in Indigenous communities focus on place-based science learning and teaching. A core idea behind this focus is that:

> The Indigenous sense of place and the importance of being in harmony are embodied in our cultural traditions. Our collective experience with the land, integrated by our myth and ritual, expressed through our social structures and arts, and combined with a practiced system of environmental ethics and spiritual ecology, gave rise to a deep connection with our Places and a full expression of ecological consciousness. (Cajete, 2023, p. xi).

Given the emphasis on "place" and its close connections to Indigenous ways of knowing and doing, numerous studies and programs have explored ways to integrate Indigenous epistemologies, perspectives, and knowledge (Jin, 2021). These studies have also listed the challenges faced in integrating these perspectives into formal classrooms. For example, Nam et al. (2013)'s study showed that teachers in nonreservation schools bordering reservations faced challenges in aligning Traditional Ecological Knowledge (TEK—a subfield of Indigenous knowledge focusing local ecological knowledge) with state science standards, while teachers in reservation schools expressed concern about the standards being based on a Western point of view and aligning it with TEK. Some scholars have proposed curricula and materials to establish connections and create frameworks that bridge Western and Indigenous science and Indigenous knowledge. For example, Sánchez Tapia et al. (2018) contextualized science curricula on inheritance and natural selection based on seven contextualization principles to support Indigenous secondary school students. They found that these principles focusing on students' cultural context and culturally influenced reasoning patterns facilitate students' learning of Western science and making connections with their Indigenous knowledge.

While there exists a substantial body of research focused on teaching science using Indigenous epistemologies and knowledge, there are comparatively fewer studies on the incorporation of Indigenous knowledge in the fields of mathematics (e.g., Furuto, 2023), technology (e.g., Bang et al., 2013), and arts education (e.g., Tzou et al., 2019). Furthermore, indigenous STEM education is a topic of interest in various countries and continents such as Canada, Thailand, Australia, New Zealand, the US, Taiwan and many more (Chinn & Nelson-Barber, 2023). Another pattern observed in the literature is that studies on engineering education for Indigenous students predominantly occur within higher education contexts (e.g., Desjarlais, 2022; Seniuk Cicek et al., 2021) and emphasize the need to "re-imagine engineering as an inclusive profession that had Indigenous people practicing (Indigineers) and effectively solving problems prior to Western contact" (Desjarlais, 2022, p.47). This shift in perspective is crucial for increasing Indigenous participation and awareness in the engineering profession and to encourage students' development of engineering identities and problem solvers. In this paper, we aim to highlight STEM education in Indigenous schools and present a holistic view that emphasizes Indigenous ways of knowing by implementing community-based engineering practices in reservation elementary schools or schools located on tribal lands. We believe this paper will make a critical contribution to the literature by presenting an approach focusing community-based engineering as a way to integrate Indigenous perspectives into engineering education and show the role of this integration in enriching learning experiences for all students.

Methods

Participants

The participants in this study included seven fifth graders (ages 10-11) and eight fourth graders (ages 8-9) (15 students in total) who attended a rural school located on a Native American Reservation in the Western U.S. Sherry, the fourth-grade teacher, is a Native American female with more than 25 years of teaching experience. Sonya, who teaches fifth grade, is also a Native American female but with less than five years of teaching experience. The two teachers have participated in the project activities including two summer professional learning (PL) sessions and implementation of community-based engineering lessons in their classrooms. In this paper, we examine the last year of the project during which these two teachers, along with the project team, collaboratively taught a community-based engineering unit, which spanned five consecutive calendar days in April 2023. All 15 students were combined into a single class and received the instruction simultaneously.

Description of the PL

Sherry and Sonya participated in two summers of PL activities. A brief overview of the summer PLs is provided below (For a more detailed description of the summer 1 PL see Hammack et al., 2021, and for the summer 2 PL see Hammack et al., 2022). During the first summer, the PL was presented in a blended manner combining asynchronous activities facilitated through Google Classroom modules and synchronous Webex meetings. The Google Classroom modules included training on ethnography and qualitative coding methods for learning about the communities in which all participating teachers (five teachers in total) taught, as well as technology-enhanced engineering curriculum using Micro:bit. Teachers were mailed a box of supplies that included everything they needed to complete the Micro:bit activities as well as a copy of the book *Ethnographic Eyes: A Teacher's Guide to Classroom Observation* by Carolyn Frank, that served as an introduction to ethnographic observation. Teachers completed the module work asynchronously before engaging in synchronous debrief sessions on Webex with the research team.

The second summer PL was also presented in a blended manner with synchronous Webex meetings following asynchronous work conducted through Seesaw Classroom. The second summer PL utilized SeeSaw Classroom rather than Google Classroom because Seesaw was the platform the most teachers were using with their own students. The asynchronous work consisted of (1) teachers sharing their experiences implementing the ethnographic studies of their school communities the previous school year, and (2) teachers interacting on Padlet, an online bulletin board, to brainstorm and share ideas about how they could design a community-based engineering lesson connected to their local context. During the synchronous Webex meetings, the research team worked with the teachers to develop their lesson plan ideas into full implementation plans.

Description of the Lessons/the Intervention

Participating teachers collectively identified that water access and quality is an issue each faces in their communities and was an issue to which students could relate. For example, the teachers indicated that water access and quality was an issue routinely faced by the community due to contamination from agriculture to a nearby river that traditionally provided drinking water and that often flooded in the spring, as well as contaminated well water on the reservation. Teachers also indicated that water access was an issue students' families often encountered as farmers and ranchers. Further, in early planning efforts the teachers suggested that their students were often motivated and engaged by technology-based curricula and had also addressed an interest each shared in potentially integrating computer science (CS) into the lessons. Consequently, the project team began researching possible engineering education curricula that could be adopted or adapted for our purposes, focusing on possible resources that offered solutions for CBE (Dalvi and Wendell, 2015) integrating Funds of Knowledge, Local Rural Knowledge, and Place-Based Education in engineering education curriculum that integrated hands-on technology and offered an opportunity to engage with CS skills. Through professional networking, the project team was introduced to the University of Nebraska Lincoln's Garden TOOLS (Technology Opportunities in Outdoor Learning Spaces) project (Ingram et al., 2020). Garden TOOLS provides curricular resources such as tutorials and help guides designed to support upper elementary students' exploration of sensors, data collection and analysis, and coding and computational thinking skills through activities focused on designing automated growing spaces and water systems. The project team introduced the Garden TOOLS resources to the participating teachers, who decided to organize the lessons on students' development of the skills and knowledge to target water access and quality challenges faced in each of their communities through the exploration of a self-watering garden that would conserve water and reduce runoff, while still meeting the moisture requirements of the plants.

On the first day of the implementation in Sherry and Sonya's classroom, the project team introduced what engineering is and shared a variety of engineering-related demonstrations with the students. These included a hydrogen fuel cell car and examples of different polymers that had been developed to meet the needs of society. On the second day, students were introduced to the concept of a self-watering garden and the various components of the Micro:bit (see Figure 1). On the third day, students engaged with sensors, including soil moisture sensor, thermometer, and water level sensor. On the fourth day, students programmed their Micro:Bit by following a given program to get the pump activated when soil moisture levels dropped under a certain measurement. The final day encouraged the students to create the whole self-watering garden with their soil moisture sensor, thermometer, and water level sensor, their water tank, and the water pump connected to the garden (see Figure 1 and 2 for the completed task). Students worked on their projects in pairs for three to four hours every day.

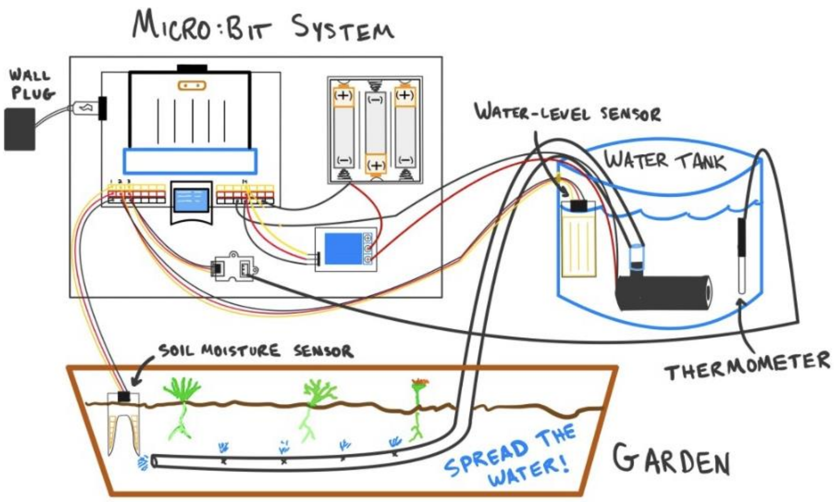

Figure 1. Sketch of the Self-watering Garden

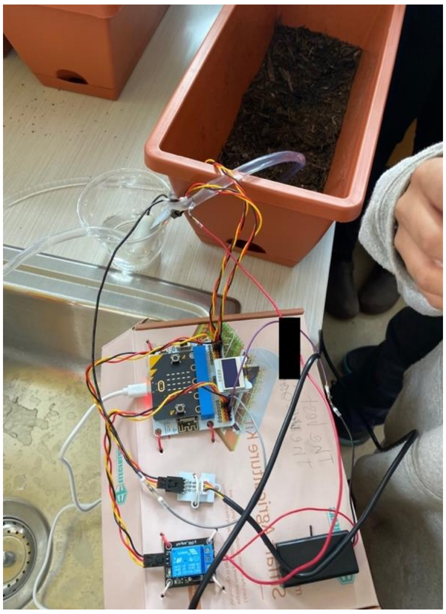

Figure 2. Students' Completed Self-watering Garden Project

Data Collection and Analysis

We adopted a mixed methods approach to answer our research questions. For the first research question *Does engagement with community-based engineering lessons result in any significant changes in Indigenous students' perceptions and attitudes of engineering?*, we utilized two primary instruments: The Engineering Identity Development Scale (EIDS) (Capobianco et al., 2012) and the Engineering & Technology subscale of the Student Attitudes toward STEM (S-STEM) survey (Unfried et al., 2015). We used the EIDS, a 3-point scale (1=No, 2=Not sure, 3=Yes) to measure Indigenous students' perceptions regarding their Academic Identity, Occupational Identity, and Engineering Aspirations. We used the S-STEM survey, a 1 to 5 Likert scale (1=Strongly disagree, 5=Strongly agree) to evaluate students' attitudes toward engineering and technology. Pre-surveys were administered in October 2022, and post-surveys were administered right at the end of the community-based engineering lessons in April 2023. Only ten students completed both pre- and post-surveys due to high turnover of students in the school. Therefore, the sample of the survey constituted these ten fifth and fourth graders. Due to the small sample size (N=10), we utilized non-parametric statistical methods for data analysis and compared pre- and post-survey scores using a series of Wilcoxon Signed Ranks Tests.

To address our second research question, *How do students experience community-based engineering lessons? What promises and needs arise in learning community-based engineering?,* we conducted interviews with a subset of students (n=9 students) at the end of the implementation. To address our third research question, *How do teachers experience community-based engineering lessons? What promises and needs arise in the co-implementation of community-based engineering lessons?,* we conducted two semi-structured 30 to 45 minute interviews with Sherry and Sonya. We conducted the first interview (post-implementation interview) with them at the end of the implementation of the lessons in April 2023 to explore their immediate perspectives on the community-based lessons they taught to the participating group of students. We had the second interview (end-of-the-year) with them at the end of the academic year to explore their perspectives and experiences with using community-based engineering as an approach to engineering education in their school on the reservation.

We developed separate interview protocols to interview teachers and students. Student interview protocol consisted of questions such as *Do you think that you can use these [engineering] skills in helping your neighbors and your family?* or *Do you think engineering can be a career option for you?* The first teacher interview protocol consisted of questions such as *What are the highlights of this week's lessons?* The second teacher interview protocol consisted of questions such as *How do you define community-based engineering?* or *What challenges did you face in teaching community-based engineering lesson?* We used Atlas.ti 23 to manage the qualitative data analysis and categorized the main themes in analyzing teacher interviews. We strived to ensure trustworthiness in analyzing interview data by upholding the four aspects of trustworthiness in qualitative research: credibility, transferability, dependability, and confirmability (Bryman, 2016). We ensured the credibility of the interview analysis through our strong and long-standing relationship with the teachers in the school and by continuously communicating with them, spending extended times in their classrooms, and co-teaching lessons with them to understand their social and cultural world. We sought to achieve transferability by providing rich accounts of the professional learning and the context of the lessons implemented with our participating teachers in their classrooms. We strived to ensure dependability and confirmability by presenting multiple excerpts and quotes from the interviews to support the identified categories.

Findings

Changes in Indigenous Students' Perceptions and Attitudes of Engineering

As seen in Table 1 and Figure 4, we found statistically significant increases in Indigenous students' academic identification with engineering (Z=-2.27, p= 0.023, r=-0.72), their aspirations toward engineering (Z=-2.14, p= 0.011, r=-0.68), and their attitudes towards the value and importance of engineering and technology (Z=-2.45, p= 0.014, r=-0.78). There was no significant change in the students' perceptions of engineering as an occupation (Z=-0.11, p= 0.915).

Table 1. Comparison of Pre and Post Survey Scores

Variables and Scales	*Pre*			*Post*					
	M	*SD*	*Median*	*M*	*SD*	*Median*	*Z*	*p*	*r*
EIDS Academic Identity	2.75	0.21	2.83	2.88	0.17	3.00	-2.27	0.02*	-0.72
EIDS Occupational Identity	2.91	0.15	3.00	2.88	0.13	3.00	-0.11	0.915	-0.03
EIDS Engineering Aspirations	2.13	0.67	2.66	2.73	0.40	3.00	-2.14	0.01*	-0.68
S-STEM (Eng & Tech)	3.07	0.85	3.63	4.77	0.65	4.77	-2.45	0.01*	-0.78

Note. *<0.05, EIDS=3 point scale (1=No, 2=Not sure, 3=Yes), S-STEM= 1 to 5 Likert type (1=Strong disagree, 5= Strongly agree)

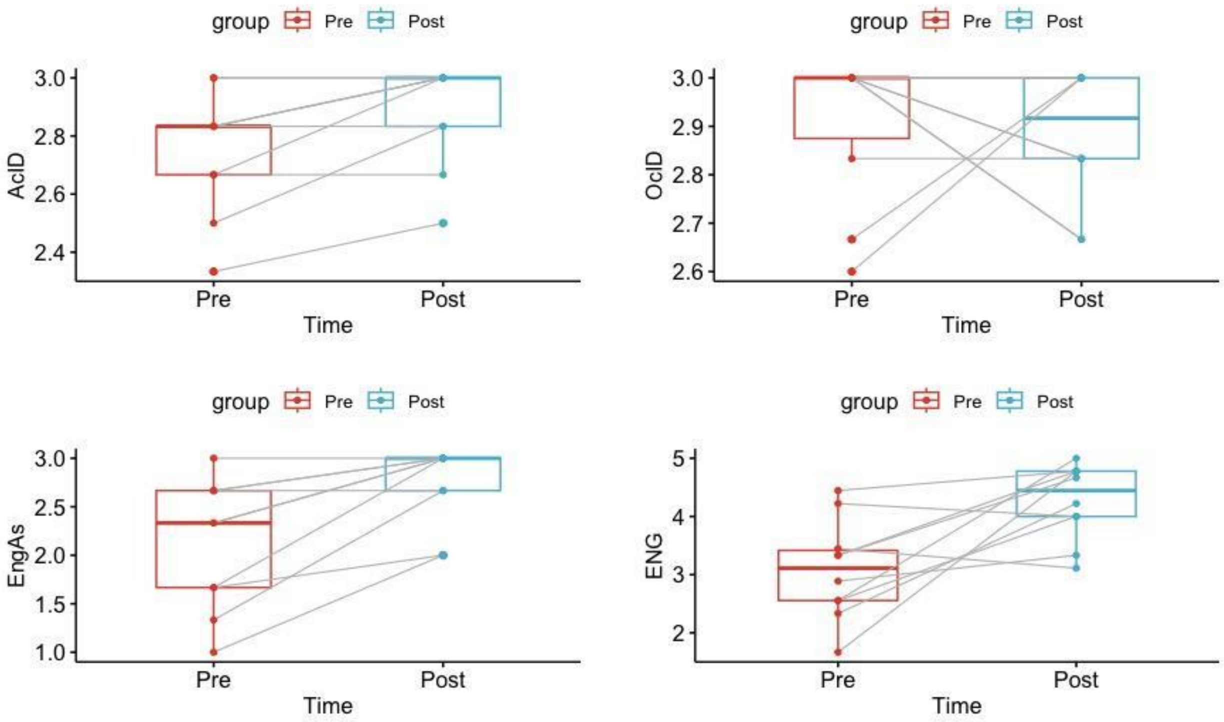

Figure 4. Shifts in Individual Scores for Each Variable (AcID= EIDS Academic Identity, OcID= EIDS Occupational Identity, EngAs= EIDS Engineering Aspirations, ENG= S-STEM (Eng & Tech))

Student Experiences with Community-Based Engineering Lessons

All students mentioned in their interviews that they enjoyed the lessons because the engineering lessons were new to them, and the hands-on aspect was engaging for them. Student 1 noted, “It was pretty fun because I was like probably the first time I ever did stuff like that.” Student 2 commented, “It was fun because I learned on how to do engineering.” Student 7 indicated that it was fun to do a hands-on project because “we got to touch dirt and plant flowers and water the plants… [the coding part was fun] because it felt like we were making a video game.” Several students mentioned how they could use the engineering skills they gained over the week to help their families or their communities. Student 1, for instance, suggested they could use their skills to help water their horses. Student 3 mentioned assisting his older brother with car issues. Student 4 expressed a desire to use their engineering skills to improve their garden or build video games. Student 2 indicated an interest in creating tools for people with disabilities. This idea of theirs stemmed from their aunt’s experience:

> Student 2: I think I can, like, make stuff too. Like if you're having a bunch of groceries, you can like make it…if I could like, have, like something that opened the door like for handicapped people.
> Interviewer: How did that, uhm, how did that idea come from?
> Student 2: Because my, my auntie, she was sick. So she had to be in a wheelchair, and we always had to open the door but if it was groceries, we had to drop it so it'd be a lot easier to have that the, like, a button or the key just to put in the door hold open and you can just close it.

Most students expressed interest in becoming engineers in the future, and almost all of them mentioned that they could become engineers to help people: "It would be fun helping people making like design like design my own stuff, products, clothes, shoes." (Student 3). Several students also expressed a desire to keep exploring engineering, particularly in the areas of building robots or creating games.

Despite their overall enjoyment, students also experienced some challenges with the projects they developed over the week. Almost all of them mentioned the difficulty of wiring tasks. For example, Student 6 said, "so my way I can't build you can't build but I kept on breaking the thing the wires. The wire kept on breaking" or Student 5 similarly indicated that it was hard to connect the wires and make sure that they remain connected. Student 1 indicated that connecting the wires to the incorrect locations would require redoing the entire wiring from scratch.

Teacher Experiences with Community-Based Engineering Lessons

Integrating Engineering into Indigenous Culture

Throughout both interviews, teachers emphasized the importance of integrating engineering into culture and avoiding the pitfall of assimilating culture in community-based engineering to ensure that these engineering lessons enrich their rich traditions and practices.

Right after the implementation of the lessons, teachers reflected on the week and indicated that students didn't have prior exposure to engineering processes and initially had difficulty understanding the nature of learning in engineering education. Sherry shared an instance she had with one of her students which reflects students' confusion:

> I think one of the biggest challenges is that these types of lessons…these aren't some of the projects that they normally do. Like today this morning [Student 1] was like, "Hey teacher. Is it okay that we're not even learning?" I'm like, "You are learning." … He's like, "Is it ok if we did not do those, reading or math." You know, and I'm like, "No, that is that's part of it."

Teachers emphasized that for students to internalize engineering concepts and processes better, it is significant to connect the lesson to their culture in addition to their community: "If there wasn't no connection there, I think it would be really difficult for them to understand that this is that they're building something, you know, they're being engineers, and they don't know it."

In their end-of-the-year interview, teachers discussed ways to connect engineering lessons to culture and suggested and experimented with incorporating cultural stories, designs, and community narratives in lessons. For example, Sonya and Sherry taught a lesson where students successfully coded a powwow on Minecraft—a virtual 3D sandbox game where users use blocks to build whatever they want. According to Sonya, this experience supported students to see a reflection of themselves and their cultures in a digital world represented in engineering and computing practices:

> I think if we can entice the culturally, the culturalist perspective to it [engineering], and bring in the, you know, a way to help students see a reflection of themselves on the other side of what this might look like, or even just, or even just navigating, like, we talk about Minecraft a lot…At one point, there was a powwow that they created on Minecraft and you know, just that, like the students being able to code something like that.

Sonya also gave other examples from their cultural stories and narratives and shared that they had challenges to explore ways to emphasize these stories and narratives in community-based engineering lessons. For example, Sonya shared about that their yearly cultural ceremony from 1860s which first was a fair of trading food items. However, in order to avoid losing its cultural significance, they brought in more cultural components to their fair such as their dances and artifacts. She recommended the importance of including such important historical cultural events and turning points into her lessons weaving seamlessly into the lessons without diminishing its cultural essence:

> Looking at sites to Yellowstone and how some of our people had transitioned down from all the way up, up, [State] down, you know… there's obviously stories that go along with them transitioning in period with the water following from the Yellowstone and then ending up in this area. And so, we're trying to figure out, I guess, our main point is like trying to figure out how we can build what is it like?

Bringing Knowledge Keepers in for the Development and Enactment of Community-based Lessons

Teachers also indicated that community and family engagement is significant in implementing these community-based lessons. They suggested involving community members and knowledge keepers in their community will help teachers and students to learn the community's perspectives. This engagement will also help community-based engineering lessons serve as a bridge between modern and traditional lives. Additionally, it allows community members to witness the value of community-based engineering lessons in their children's lives, which in turn increases the value students give to these lessons. For example, Sonya shared:

> Integrating the cultural perspective, and then even stories, you know, like our knowledge keepers, our elders, who hold a significant piece within our communities that might be willing to share and, you know, just even identify the importance of what this project [community-based engineering implementation] does, and, you know, how, why it holds value to them, … the parents and the elders, and you know, the community members truly do value what the students are doing.

Teachers were also struggling because the engineering words used in lessons were not naturally a part of the students' Indigenous language. They proposed to include the language in the learning and even to create new words in their language that matched the engineering terms. Sonya asked, "How can we link that? Or even find words, terminology...there is some terminology there, but our language doesn't have words for engineering." They said that engagement with community people who know a lot about science or language could help them to create words or phrases that work with both their Indigenous language and the engineering ideas.

Furthermore, Sherry highlighted bringing in Indigenous engineers in classrooms for students to connect and relate to them: "One of the things that I want to do is bring in like realist like realistic people. You know, that way the students can connect to that." Indigenous community members who became engineers can serve as role models for elementary students living on the reservation and highlight ways in which engineering can benefit their home communities.

Administrator Support and Funding

Teachers believe that the support of the school administration is very important when it comes to engineering projects. Sonya shared that they had their administrative support, which enabled their implementation of community-based engineering projects. However, Sonya also shared that to be able to continue being on the project and sustain these practices, it was also critical for them to share with administration what they needed and how their students were benefiting from community-based engineering projects. Funding was another significant component of their continuation in the project. Teachers shared that without the funding they received through the project, they would not do the engineering lessons or projects and continue implementing them in their classroom over the years due to the expense of instructional materials.

Students' Development of Soft Skills

In the post-implementation interview, teachers frequently discussed that the community-based engineering projects enabled students' development of soft skills such as patience and focus. Sherry emphasized, "they've had to learn a lot of patience in this" and Sonya added:

> I think one of the highlights [of the lessons] is like them understanding the process. And following directions. I think that's one of the biggest things that we've emphasized from the beginning, was that you need to take your time and follow the direction.

Furthermore, teachers discussed the collaborative nature of the tasks. "A lot of teamwork" was emphasized as a key outcome, and students built on their collaborative problem-solving by "having to work together and listen to another person's idea or, you know, being respectful." In addition to the collaborative problem solving, teachers also pointed out the presence of student agency and independent problem solving. This was evident when students were tasked with identifying what an engineer might build. The initial confusion—"What do you think it is? They were like, what is it? What do we do what?"—gradually gave way to collaboration, with students "helping each other figure it out." This whole process helped students to identify themselves with the profession. Sherry put forward, "when we're done with this, you go back and you ask them now, what is an engineer? You know, what do you want to be when you grow up? About three fourths will say an engineer."

Hands-on and Integrative Nature of the Lessons

In the post-implementation interview, teachers highly valued the hands-on and integrative nature of the community-based lessons and the project. Sonya expressed that many students come to science class and expect a mostly textbook-based teaching, and the hands-on nature of the engineering tasks make differences in how students view science:

> Science is always a challenge for many of our students. Because they come in from this view that with science, we're just gonna sit there with pen and paper… if we were to sit there, and we could ramble on about all these fancy terminology stuff…it doesn't make any sense to them. That doesn't have any meaning.

Similar to students' experiences discussed above, teachers also indicated that students felt frustration when the tech component does not work while working on their engineering projects. Teachers noted the frustration students felt when they could not connect the Micro:bit to their devices or download necessary components. Another challenge was the wiring aspect of the self-watering garden project. Despite these challenges, teachers also indicated that these moments created moments of further collaboration among student groups and made the problem-solving aspect more meaningful, as Sherry pointed out:

> The only good thing, like I had two boys that finished early and got everything right. So they went around and started helping and figured out they've put their the connection in the wrong place. The wires in the wrong spot. So they, so they, what they did was they just went to every one of them trying to help. And that was very successful.

Discussion

The findings from this study shows that the CBE framework integrating insights from funds of knowledge (Moll et al., 1992), LRK (Avery, 2013), and PBE (Gruenwald, 2003) proved to be an effective approach to engineering education in making engineering relevant and accessible to Indigenous students. The community-based engineering lessons the students engaged with were connected to a local need that all members of the class were aware of. This connection to community was an important aspect of engaging students in the lessons. The quantitative findings from this study suggest that following the intervention, the students more strongly identified with engineering, strengthened their aspirations toward engineering as well as their attitudes toward the value of engineering. These conclusions are substantiated by the qualitative findings. The cultural connection to community was evident in the students' interview responses, which indicates that students were transferring elements of the engineering that they did during the lessons and thinking about broader implications for their communities. For example, students shared how the skills they developed could be used to address challenges their families, friends, and communities face. The research literature has shown a disconnect between Indigenous culture and engineering, with Indigenous students sharing that they do not see how engineering would benefit their home communities (Kant, 2015). Unlike in the Kant paper, the students in this study saw engineering as a way to potentially help their community or family members. By centering engineering design tasks around a problem that was local to the community, the students were able to see a tangible way that engineering could be helpful to them. Having experienced this concrete example of engineering situated within the local community could have allowed the students to imagine additional ways that engineering could help their reservation community.

The perspectives shared by teachers on CBE and community-based engineering lessons they taught in their classrooms emphasize the crucial role of integrating Indigenous culture and epistemologies into engineering lessons. This finding is crucial in understanding the successful implementation of CBE in Indigenous communities. It suggests that culture should not merely be an add-on to engineering lessons. Engineering education should be intricately woven around Indigenous culture and epistemologies. This approach aligns with our theoretical framework that highlights the importance of LRK (Avery, 2103), where cultural context is not peripheral but a driving force in the development and implementation of engineering, and more broadly, STEM lessons in Indigenous contexts.

Teachers suggested several crucial needs and strategies to enhance the cultural relevance of CBE in Indigenous school contexts. One particularly insightful strategy was inviting community knowledge keepers into classrooms to share their perspectives and insights on community problems. Such involvement can encourage students to effectively blend traditional wisdom with contemporary engineering practices. Additionally, involving community members in the development of engineering curricula represents another promising area of action. This approach can strengthen the position of CBE in Indigenous communities. Another strategy teachers proposed and we found highly enlightening was inviting these community members to create engineering terminology in Indigenous languages to enhance the cultural and linguistic relevancy of engineering for Indigenous communities. Teachers also emphasized the importance of administrator support and funding in implementing CBE in schools. This finding aligns with previous findings on the role of administrators and funding in the sustainability of engineering education in elementary schools (Boz et al., 2023; Hammack & Ivey, 2019), and more broadly, with the integration of any new STEM practice in these settings (Boz et al., 2023). The literature also extensively demonstrates the role of engineering lessons in developing soft skills, or 21st-century skills (e.g., Lachapalle & Cunningham, 2014), a point also noted by Sherry and Sonya as being particularly promising in implementing engineering lessons in their schools.

One challenge that both teachers and students faced during the engineering lessons on self-watering gardens was the use of wires and troubleshooting issues related to the Micro:bit connection to the computer. More elaborate tutorials and help guides seem to be deemed necessary for a more successful integration of CBE. In addition, the lack of significant change in students' perceptions of engineering as an occupation suggests that while interest and engagement are enhanced, transforming these into career aspirations may necessitate more sustained exposure to engineering lessons in Indigenous contexts.

Next steps in this research should include leveraging the engagement and focus on community problems research and plan solutions to those issues faced by the community, and construct prototypes for those solutions (Davli et al., 2016). At that stage, research team and teachers could collaborate with and gain input from stakeholders like local Indigenous scientists, tribal leaders, and other community educators to integrate multiple perspectives into the engineering solutions the students are exploring (Tan et al., 2019). Doing so, would build upon LRK (Avery, 2103) and contribute solutions to address those critical community needs.

In conclusion, this study has provided valuable insights into the potential of CBE to increase Indigenous students' interest and engagement with engineering and empower Indigenous students to see engineering as a means to address the needs of their communities. This study highlights the importance of weaving Indigenous culture and epistemologies into engineering education, rather than treating them as peripheral elements. Involving community members in this process holds great promise for the future of STEM education in Indigenous communities.

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Author Information

Tugba Boz
https://orcid.org/0000-0002-8020-127X
Purdue University
United States
Contact e-mail: *tboztogu@purdue.edu*

Rebekah Hammack
https://orcid.org/0000-0002-8621-1006
Purdue University
United States

Nicholas Lux
https://orcid.org/0000-0002-7434-0660
Montana State University
United States

Paul Gannon
https://orcid.org/0000-0003-0888-8158
Montana State University
United States