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Board 297: Impact of Community-based Engineering Lessons on Rural and Indigenous Elementary Students

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Background

Engineers are tasked with solving the world's problems, and the engineers of the future must have diverse perspectives that represent the diversity of the world population. This will require educators to recruit and prepare students who come from backgrounds that are traditionally underrepresented in engineering, such as those who live in rural and reservation communities. Students hailing from these communities possess unique funds of knowledge [1] that will help to address various engineering problems.

Because career choices are often made before middle school [2], it is important to start exposing all children to engineering in elementary school. Exposing elementary students to engineering requires elementary teachers to be prepared and confident in their abilities to teach engineering. Unfortunately, many elementary teachers feel underprepared to teach engineering [3] and may even avoid teaching it. Consequently, better understanding elementary teachers' perceptions of effective and inclusive engineering education could be leveraged to help them build their engineering self-efficacy. As a result, elementary teachers might then be better equipped to build students' engineering identity and encourage them to consider engineering as a potential career option.

In addition to helping students develop engineering identities, exposure to engineering in elementary school is also beneficial for developing students' engineering habits of mind (EHoM). EHoM are internalized dispositions and ways of thinking that engineers draw upon when confronted with problems [4] and include things such as optimism, persistence, collaboration, creativity, systems thinking, and attention to ethical considerations [5]. These EHoM can be beneficial to all students, regardless of career choice, but as with all habits, EHoM take time to develop. As such, it is important for teachers to provide students with opportunities to develop EHoM throughout their K-12 school years [6].

This study addresses those challenges and is based on a multi-year project that focuses on equipping elementary teachers with the tools to implement place-based and community-based engineering lessons in their classrooms. As recognized in *The Framework for P12 Engineering Learning* [6], teachers are called to develop classroom engineering design tasks that connect to the local context. Engaging students in place-based learning can help connect students' home lives with school curriculum and has been shown to enhance student mastery of science content knowledge and skills [7-9]. Place-based learning can also provide students with opportunities to apply their unique funds of knowledge which can also enhance their learning [10-12]. In this paper, we examined the effects of our participant teachers' community-based engineering lessons on their students' attitudes and perceptions toward engineering during the 2022-2023 school year.

Our research questions for this paper are:

1. Do students' perceptions and attitudes toward engineering differ with the implementation of community-based engineering lessons, and do these differences vary across school context (reservation/rural vs small town/rural)?
2. What are elementary teachers' perspectives about their teaching and their students' learning of community-based engineering in their classrooms?

Methods

The current work is part of a larger, multi-year study designed to increase awareness and preparedness of rural and indigenous youth to pursue engineering and engineering related careers. During the first portion of the grant, we worked with elementary pre and in-service teachers in rural and reservation communities to identify local funds of knowledge and use that in the design of classroom curriculum. During this second portion of the grant, we are assisting teachers with the implementation and refinement of their designed curriculum.

Participants and Context

The participants included fourth and fifth grade (*N*=5) elementary teachers in rural and reservation communities in the Western US and the students enrolled in their classes. Their backgrounds are outlined below (all names are pseudonyms). The teachers were employed in schools in reservation and rural areas or small towns (see Table 1).

Table 1

Participant Demographics

Case	Teachers	Context	Grade	Student Survey Participant Numbers
1	Sherry (Native American)	Reservation and rural	4th Grade Native American Students	6
1	Sonya (Native American)	Reservation and rural	5th Grade Native American Students	4
1	Courtney (White)	Reservation and rural	5th Grade Native American Students	10
2	Holly (White)	Rural (Small town)	4th Grade White	15
2	Jennifer (White)	Rural (Small town)	5th Grade White	9

Data Collection and Analysis

To address our first research question, we used two survey instruments: 1) the Engineering Identity Development Scale (EIDS) [13]; and 2) the Engineering & Technology subscale of the Student Attitudes toward STEM (S-STEM) survey [14]. We used the EIDS to compare students' pre and post scores in their perceptions regarding their Academic Identity, Occupational Identity, and Engineering Aspirations. We used the S-STEM survey to examine students' pre and post survey scores in their attitudes toward engineering and technology. In some schools, there was student turnover, therefore we only included the survey results from students who completed both pre-survey and post-survey (see Table 1). We conducted a two-way mixed ANOVA analysis including two main effects (Time and Context: Reservation/Rural and Small Town/Rural) and one interaction effect (TimeXContext) after we ensured that the assumptions of normality and homogeneity of variances were met. To address our second research question, we conducted interviews with the teachers. The interviews consisted of questions such as *What was your biggest support in teaching engineering? Why?* or *What would pull your students in or would hold them back in engineering lessons?* Each interview lasted approximately one hour.

Findings

As seen in Table 2 and 3 below, there was a significant change across students' scores in their perceptions of occupational identity (OcID), $F(1,1) = 15.26$, $p < .001$, $\eta^2 = 0.16$. There was no change on students' scores in terms of their perceptions of academic identity (AcID), engineering aspirations (EngAs), and their attitudes toward engineering and technology (ENG) ($p = 0.12$, $p = 0.49$, $p = 0.41$, respectively).

The interaction between time and school context was significant in the AcID ($F(1,1) = 7.09$, $p= 0.00$, $\eta^2 = 0.11$), OcID ($F(1,1) = 10.40$, $p = 0.00$, $\eta^2 = 0.11$), EngAs ($F(1,1) = 5.94$, $p = 0.02$, $\eta^2 = 0.07$), and ENG scores ($F(1,1) = 9.57$, $p = 0.00$, $\eta^2 = 0.11$). The results suggest that the effect of community-based engineering lessons on students' perceptions and attitudes significantly varied across different school contexts and over time. The significant interaction between time and context in the AcID, OcID, EngAs, and ENG scores can be attributed to the changes in the scores across the schools in the reservation areas, where the mean scores consistently increased from pre- to post-survey (see Table 2).

Table 2

Mean Scores and Standard Deviations

Variables	Context	Time	M	SD	Variables	Context	Time	M	SD
AcID	Reservation	Pre	2.68	0.23	EngAs	Reservation	Pre	2.18	0.66
	(*n*=19)	Post	2.74	0.26		(*n*=19)	Post	2.53	0.49
	Small Town	Pre	2.78	0.21		Small Town	Pre	2.21	0.34
	(*n*=24)	Post	2.55	0.31		(*n*=24)	Post	2.01	0.55
	Total	Pre	2.74	0.22		Total	Pre	2.19	0.50
	(*N*=43)	Post	2.63	0.30		(*N*=43)	Post	2.24	0.58
OcID	Reservation	Pre	2.83	0.19	ENG	Reservation	Pre	3.33	0.80
	(*n*=19)	Post	2.88	0.13		(*n*=19)	Post	3.98	0.65
	Small Town	Pre	2.38	0.51		Small Town	Pre	3.82	0.93
	(*n*=24)	Post	2.87	0.25		(*n*=24)	Post	3.44	0.63
	Total	Pre	2.58	0.46		Total	Pre	3.60	0.90
	(*N*=43)	Post	2.87	0.20		(*N*=43)	Post	3.68	0.69

Table 3

Two-Way ANOVA Results

	Source	*SS*	*df*	*MS*	*F*	*p*	η^2
AcID	(Intercept)	612.25	1	612.25	9245.03	<.001	0.99
	Context	0.03	1	0.03	0.50	0.48	0.01
	Time	0.16	1	0.16	2.44	0.12	0.03
	Time X Context	0.47	1	0.47	7.09	0.01*	0.08
OcID	(Intercept)	636.09	1	636.09	6203.72	<.001	0.99
	Context	1.13	1	1.13	11.00	0.00*	0.12
	Time	1.57	1	1.57	15.26	<.001*	0.16
	Time X Context	1.07	1	1.07	10.40	0.00*	0.11
EngAs	(Intercept)	422.26	1	422.26	1590.34	<.001	0.95
	Context	1.22	1	1.22	4.59	0.04*	0.05
	Time	0.13	1	0.13	0.49	0.49	0.01
	Time X Context	1.58	1	1.58	5.94	0.02*	0.07
Eng	(Intercept)	1127.03	1	1127.03	1906.71	<.001	0.96
	Context	0.01	1	0.01	0.02	0.88	0.00
	Time	0.40	1	0.40	0.68	0.41	0.01
	Time X Context	5.66	1	5.66	9.57	0.00*	0.11

Note. *p<0.001

The preliminary analysis of the teacher interviews showed that all the teachers emphasized the importance of integrating local issues into their engineering lessons, such as building cardboard houses to explore ways to keep homes warm or cool without air conditioning.

Courtney gave an example from the project she implemented in her classroom and shared, "we built the cardboard houses talking about ways that we can you know, keep our homes warm or cold during the winter…because that's an issue; they [students] don't have air conditioning." Teachers proposed that their community-based engineering lessons enhanced their students' engineering identity. Sonya shared, " trying to entice it with what's going on in your community... making those connections does help piece those things together [for students]." Sherry noted, "And when we're done with this [project], 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."

Another recurring theme across all the participants is the connection between engineering and students' development of problem-solving skills and teamwork, both skills recognized as engineering habits of mind (EHoM) [5], [15]. Sonya reflected on the challenges of promoting teamwork in her lessons and how engineering lessons help her build teamwork and collaboration skills, "Taking turns is one of, is another area that they struggle with. I mean, they're kids, they want to be ahead all the time, or in first or line leader or you know, but this itself is helping them collaborate and discuss." Sherry emphasized, "Teamwork was one of the biggest things, because a lot of the times you want to see, a lot of the kids want to see themselves doing it by themselves… They got better at figuring out, oh, we need to work together. And oh, I have to listen to this other person’s idea because their idea is better than my idea.

Teachers working in reservation areas stressed the importance of connecting engineering lessons with history and culture. Courtney stressed importance of closely aligning engineering lessons with history and used it as a strategy to introduce engineering in her classroom:

Everything that the Native Americans did in their history was engineering because they would take the Buffalo and then they found something to do with every part of it, to meet a need that they had. So, we kind of start off that way and then we move on to like problem solving and read a lot of texts about inventors, and there's a lot of survival books that we read.

Despite the positive outcomes, teachers also encountered some challenges such as time constraints, resource limitations, and students' fear of making mistakes. However, despite these challenges, all the teachers expressed their interests to continue teaching community- based engineering lessons in their classrooms.

Discussion

This study emphasizes the integration of place-based learning within community-based engineering lessons and providing meaningful engineering learning experiences for students from diverse backgrounds. By leveraging the unique knowledge of students and their communities, teachers can enhance students’ development of engineering identity and help students view engineering as a potential career option. The findings reveal the interesting interplay between community-based engineering lessons and students' perceptions of engineering across schools located in both rural and reservation areas. In particular, there was a significant increase in students' occupational identity (OcID) scores in total and across different school contexts (reservation/rural vs small town/rural) after students were exposed to community-based engineering lessons. The interaction between time and context was also significant in students’ perceptions of academic identity, occupational identity, engineering aspirations, and their attitudes toward engineering and technology. It is notable that reservation areas showed consistent growth in mean scores across these variables.

The teacher interviews reinforced this trend and highlighted that community-based engineering lessons enhanced their students' engineering identity. Teachers recognized the importance of connecting lessons with place in rural communities and, particularly history and culture in reservation areas. Further, teachers recognized the role that the community- based engineering lessons were having on the development of students’ problem-solving and collaboration skills, which are identified as the essential skills [5], [15] and represent “how engineers actually think” [16]. These findings are encouraging given calls for policy makers and educators to reconsider how best to integrate those EHoM through pathways such as fully integrated STEM education that builds on connections between the disciplines [5]. Providing teachers with opportunities to reflect on the role of EHoM in their engineering instruction, and not only the development of their own EHoM, but the development of their students’ EHoM, could provide keen insight into their engineering self-efficacy. In turn, teachers might also more clearly recognize the positive influence of community-based engineering curricula, and ultimately be encouraged to continue facilitating their students’ engineering identity development and career interest.

Next Steps

During the initial years of the project, the research team actively visited the teachers during portions of their engineering lesson delivery. During this final year of the project, the research team will not be present during any delivery of the lessons. Rather, we will be providing support in the form of providing classroom materials and other resources the teachers might request. We have already collected teaching efficacy survey data from the teachers at the beginning of the project and at the end of each project year. We will collect a final set of survey data this last project year, as well as conduct final exit interviews with the participating teachers. The intent of the final data collection and analysis will be to identify if teachers' initial efficacy gains were sustained in the absence of face-to-face classroom contact with the research team. We also want to know if the teachers viewed differences in the ways they implemented engineering during the absence of the research team.

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