ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #37215

Using Engineering Design Tasks to Create Indigenous Cultural and Community Connections with the Classroom for Elementary and Middle School Students (WIP, Diversity)

Frank Bowman

Dr. Frank Bowman is the Thomas C. Owens Endowed Chair of Chemical Engineering, Associate Professor, and Chair in the Department of Chemical Engineering at the University of North Dakota. He holds a Ph.D. from the California Institute of Technology and a B.S. from Brigham Young University, both in chemical engineering. His research interests include atmospheric aerosols, assessment of student learning, and K-12 STEM education

Bethany Jean Klemetsrud

Beth grew up in Devils Lake and on the White Earth Nation. Klemetsrud, who teaches unit operations, ethics, and lab classes, conducts research in renewable energy, broadening participation, and sustainability assessment. She is currently an assistant professor in Chemical Engineering at the University of North Dakota

Julie Robinson (Professor)

Emine Ozturk

Using Engineering Design Tasks to Create Indigenous Cultural and Community Connections with the Classroom for Elementary and Middle School Students (WIP, Diversity)

Background

This work in progress paper describes initial efforts from the first year of a three-year project [1] to help elementary and middle school teachers create and implement culturally relevant engineering design tasks in their classrooms. The teachers within this program teach grades 3-8 and work within school districts with a large Native American population, located on or near tribal communities.

Implementation of the Next Generation Science Standards (NGSS) [2], requires that K-12 teachers integrate engineering design into their curricula so that students see both the intertwined nature of engineering with other disciplines, as well as its implications for solving social and environmental issues. This expectation can be challenging for teachers who may feel they lack the training and self-efficacy to effectively implement open-ended engineering problem-solving experiences in their classrooms. This is additionally difficult for schools in rural and Native American settings, as resources and support may be limited [3]. Curriculum is often presented from a Western framework that does not incorporate cultural knowledge, values, and beliefs embedded in a community [4]. Oftentimes, engineering design tasks are thought of as acultural and devoid of community inclusion and values. However, engineering design is inherently a cultural endeavor as problems needing engineering solutions or design thinking are situated in a specific community and need community solutions. Furthermore, the engineering design process itself has many features that align with principles of culturally relevant pedagogy.

The professional development (PD) model enacted focuses on developing and improving teacher's self-efficacy when teaching engineering with cultural connections and uses a cohort model that embraces concepts from Bandura's Social Learning Theory [5]. We also synthesize frameworks put forth by Ladson-Billings [6] and Gay [7] for culturally relevant and culturally responsive instruction to guide our project and its research objectives. Both frameworks are grounded in research that examines successful teaching practices across cultural communities and groups, including Native Americans, and identify common components that support diverse students' academic achievement and engagement. For the sake of consistency in language, we use the term "culturally relevant" to encompass our definition and project goals. Inherent in its design, this project uses the participants' families, schools, and communities as sources of strength, guidance, and inspiration for both the PD offerings for teachers as well as within the subsequent engineering design tasks that are developed for classroom implementation. Our aim is to model culturally relevant instruction, incorporate a culturally relevant engineering design approach within this research project, provide explicit instruction for teachers with the frameworks, and explore teachers' adoption of such practices as they implement their classroom engineering design tasks.

Approach

To integrate best practices for culturally relevant engineering design pedagogy, the engineering design cycle framework developed by the UTeachEngineering program [8] was adapted to specifically address community needs and cultural values. As shown in Figure 1, this Culturally

Relevant Engineering Design (CRED) Framework orients each step of the engineering design cycle with questions focused on community and student cultural needs, values, and expectations. To aid teachers with classroom implementation, culturally relevant instructional strategies accompany each design step. General principles of culturally relevant instruction are also provided.

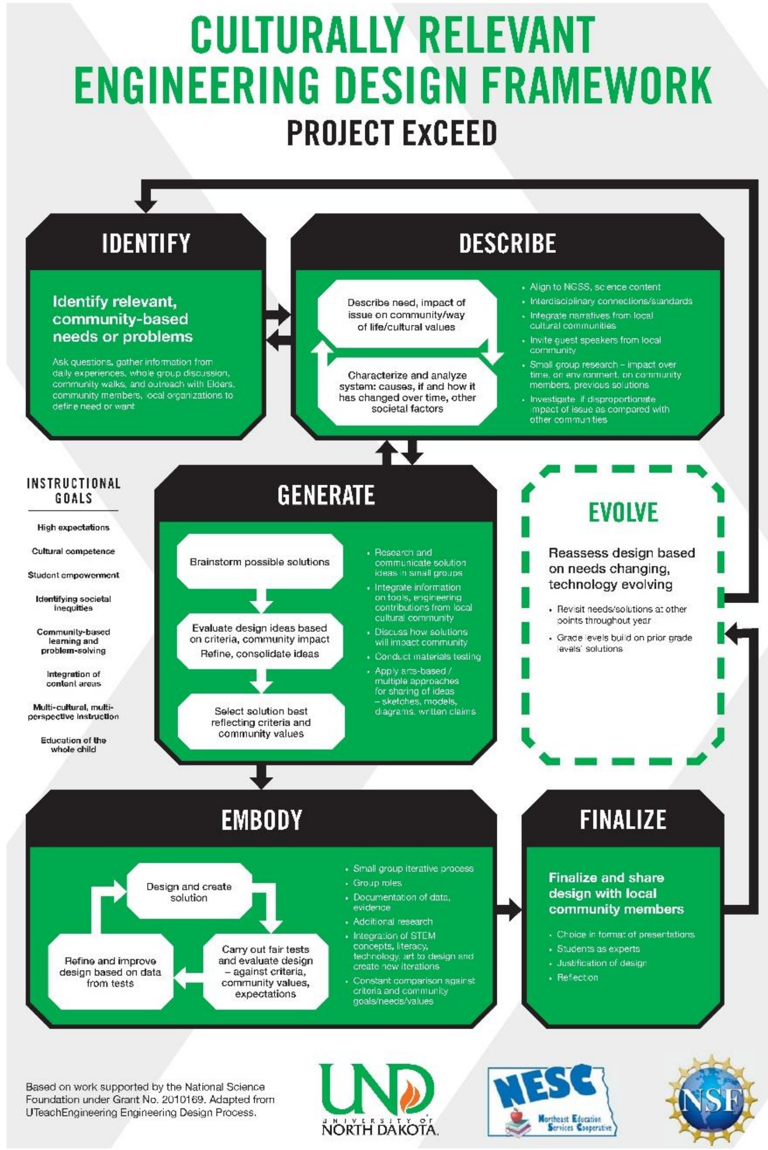

Figure 1: Culturally Relevant Engineering Design (CRED) Framework, adapted from [8]

An ongoing PD program was designed to help teachers learn about and gain confidence in using engineering design and culturally responsive approaches in their classrooms. A first cohort of 8 teachers from three school districts in rural North Dakota with large Native American student populations began participating in the program in 2021. A key goal of the program is to create collaborative partnerships allowing teachers to support and learn from each other in future years.

The PD program included a three-day virtual session in June, a two-day session in August, and several full, half day, and evening workshop sessions throughout the school year. In the first summer session, teachers were introduced to engineering design as they worked together in teams to complete a hands-on water filtration design task that was situated in Native American cultural concepts, with the book "*We are Water Protectors*" [9] providing additional cultural grounding. Within the Dakota language there is a phrase often used, "*Mni Wiconi,*" which translates to "water is life". The sacredness of water is well understood within Native communities in North Dakota. Within the region where the PD took place, teachers additionally understood the importance of water when it comes to farming, wetlands, and economic incentives from recreational tourism. The importance of each engineering design framework step was discussed, and then the teachers emulated that portion of the process. During the entire design process, emphasis was placed on connecting engineering design to their community and to local tribal communities.

Throughout the summer PD, many resources were shared, including: 1) science and engineering standards websites [2], [10], [11] for help navigating NGSS, state standards, and supporting materials; 2) the North Dakota Native American Essential Understandings (NDNAEU) [12], which describe elements critical to Native American ways of knowing to guide the learning of all students across the state; and 3) North Dakota's Teachings of our Elders website [13] with Native American Elder video interviews, lesson plans, and other materials to help integrate the NDNAEU into classrooms, curricula, and engineering design. Similar information is available for other states and tribal communities, e.g., [14]-[16]. By the end of the June PD, teachers had a better understanding of the engineering design framework, the ability to align grade-level NGSS standards with design tasks, and resources and skills to become culturally responsive teachers.

The second summer session focused on creating and giving feedback on teachers' lesson plans for their fall classroom implementation of their engineering design tasks. Teachers tailored the water filtration design task from the June PD to fit within their existing curricula. This process was guided by a lesson plan template adapted from Understanding by Design (UbD) [17] to include the engineering design steps and cultural and community connections. We also worked with the teachers to develop a streamlined student-friendly version of the CRED framework that they used in their classrooms to introduce the engineering design process. The school year PD days focused on further developing and finalizing teachers' lesson plans, with an emphasis on strategies for differentiating STEM instruction for students across various abilities.

Initial assessment of the summer PD sessions indicates that teachers are developing a better understanding of the engineering design process and self-efficacy within their teaching and implementation of engineering design tasks. Pre-post results on the Teaching Engineering Self-Efficacy Scale (TESS) [18] from before and after the summer PD showed statistically significant increases in average scores on the engineering pedagogical content knowledge self-efficacy subscale (+1.7 on a 5 point scale) and overall self-efficacy in teaching engineering (+3.3 on 20 point scale). Qualitative teacher feedback from focus group interviews and written and verbal reflections also supported this finding of increased self-efficacy, with teachers generally entering each new PD session or classroom implementation with some level of anxiety but leaving with additional confidence and enthusiasm. More in depth analysis of additional quantitative survey data, coding of interview responses and classroom observations, and evaluation of lesson plans is ongoing and will be completed after teachers complete a round of post implementation surveys and interviews.

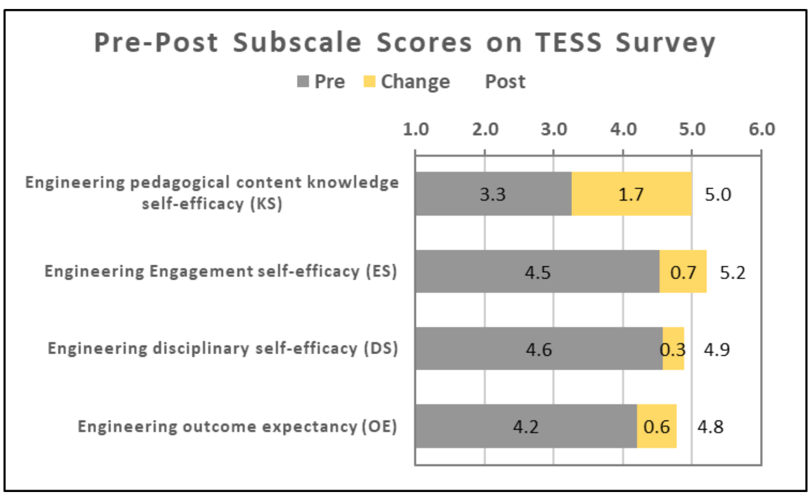

Figure 2: Pre-Post Subscale Scores on TESS Survey

Case Studies

During classroom implementation of the water filtration design task, students were introduced to the CRED framework and then divided into small groups and asked to brainstorm and develop questions as to how water quality affected their daily lives and their local and tribal communities. (Describe stage). Teachers then provided either pre-made "dirty" water or collected water from local lakes or other wetland areas. Filtering materials (coffee filters, air filters, sand/gravel, cloth and surgical masks, paper towels, vacuum bags, water filters, etc.) were provided and students were asked to brainstorm designs (Generate). Once students completed their brainstorming sessions, they were tasked to create a physical model for water filtration (Embody) and test their designs by passing their dirty water through various filters. Students encountered designs that did not work the first time and were encouraged to keep brainstorming and improving their designs. To culminate, students presented their designs and the measured outcomes (Finalize). The engineering design task embodies cultural components and was framed to meet each community's needs. Below are two case studies showing how teachers were able to implement this design task with their classrooms. The content standards guiding each lesson are listed at the beginning of the case study.

Case Study 1: Team Teaching between 8th Grade English and Science Classrooms

- **W.2, W.4, W.6:** Write explanatory texts, Write clear and coherent to a specific task, Use technology to produce writing.
- **L.2:** Spelling, Grammar, Mechanics
- **MS-ESS3-1:** Construct a scientific explanation based on evidence for how the uneven distribution of Earth's minerals energy and groundwater resources are the result of past and current geoscience processes.

This team-taught lesson plan closely reflected what was described above. To make STEM relevant within the English and science classrooms, the English teacher covered the Identify and Describe stages, while the science teacher focused on the Describe stage (relevant to the science standards) as well as the Generate and Embody stages. In the English classroom, the teacher used anticipation guides and focused on formative assessment of the above standards. Students explored various resources, compiled information on water issues within their local and nearby tribal community, including health of the lake, Lemna wastewater plant, farming and outdoor recreation. Students used the NDNAEU's Teaching of Our Elders website to listen to Indigenous perspectives of water issues. In the science classroom, the Describe stage was expanded to bring in the science standard listed above. The teacher focused on these concepts and connected them to the anticipation guides that they had completed in the English classroom. Students were given different materials and had 3 class periods to complete the design. The science teacher then had students use the information they had researched in English class and present their working water filtration model, including data they collected, how much clean water was produced, opacity of the water, and how long it took for their design to filter the water. To wrap up the team teaching, the English teacher had the students learn about writing informal text structures by reflecting on their design tasks.

Case Study 2: 5th/6th grade Classroom

- **3-5-ETS1-1:** Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

Within the upper elementary classrooms, teachers had more control over integrating engineering design across their curricula. Presentations/posters could be part of their English time, and cultural aspects could be connected to their social studies lessons. Implementation was similar to that described above. For the cultural connection, in addition to reading "*We are Water Protectors*", the teacher had students visit the NDNAEU website and explore the "Water Protectors' ' lesson plan. The teacher did have to make modifications for the engineering components to be more relatable to upper elementary age students. Students were allowed to pick two filtering materials, and they used a pre-made dirty water solution. Students were incredibly engaged in the Generate and Embody stage. All students regardless of learning levels and prior engagement in other activities, participated actively and contributed to improving the model. To make the project more tactile, the teacher facilitated the students building a contraption out of pasta to hold their water filtration device. Students embraced when their designs failed and were extremely creative problem solvers when it came to improving both their water filtration device and their pasta contraption.

Teacher Feedback and Key Takeaways

The most positive theme across the teacher interviews was the amount of engagement and ownership that all students had within this project. Students who generally struggle within STEM courses or group work, excelled in this design task; they felt a sense of ownership within their project when solving a local environmental issue. A common issue was teachers misjudged the timing of this task. They had allotted one-two class sessions for the first iteration of Generate and Embody, whereas it took three. With facilitation during one of our PD days after the first task implementation, teachers brainstormed together about setting clear goals and deliverables for each day to move at a faster pace. During post task interviews, most teachers mentioned how stressed they felt at the beginning of the task, but as the task progressed and they were able to see student engagement and learning, they became more confident in their STEM teaching skills. A majority of teachers identified that their largest growth area was the need to connect to the cultural component throughout the Generate and Embody stages, not just the Describe stage. Teachers discussed having community experts and area Tribal Elders come to the classroom during those stages to have students continuously tying back to the Identify and Describe stages.

Future Work

For the next two years of this project, the research team will continue to evaluate results from the TESS and other survey instruments, analyze classroom implementation videos and lesson plans, and assess for improved self-efficacious behavior from the teachers, along with their use of culturally relevant pedagogy within the engineering design task. To improve summer and school year PD days, the team will continue to gather formal and informal feedback from this year's cohort of teachers. The research team will continue to guide teachers on how best to integrate engineering tasks within pre-existing curricula. During the remainder of this school year, teachers will implement two more design tasks and complete assessments through survey and video observations. This will allow for a more robust analysis of teachers' self-efficacy. For the summer 2022 PD, a new cohort of teachers will begin this project. This new cohort will not only benefit from a more refined PD but will have the first cohort serving as mentors for them throughout the duration of the project.

References

[1] "Project ExCEED, Exploring Culturally relevant Engineering Education Design" https://sites.google.com/nescnd.org/projectexceed/home (accessed Apr 18, 2022).

[2] "Next Generation Science Standards." https://www.nextgenscience.org/ (accessed Feb 1, 2022)

[3] P. Boyer, *Building community: reforming math and science education in rural schools*. Fairbanks, AK: National Science Foundation, 2006.

[4] D. Levy, "Bridging Tribal, Technological Worlds," *Science*, vol. 258, p. 1231, 1992, doi:10.1126/science.258.5085.1231

[5] A. Bandura, "Self- Efficacy: Toward a Unifying Theory of Behavioral Change" *Psychological Review*, vol. 84, no. 2, pp. 191-215, 1977, doi:10.1037/0033-295X.84.2.191

[6] G. Ladson-Billings, "Toward a theory of culturally relevant pedagogy," *American Educational Research Journal*, vol. 32, no. 3, pp. 465-491, 1995.

[7] G. Gay, "Preparing for culturally responsive teaching," *Journal of Teacher Education,* vol. 53, no. 2, pp. 106-116, 2001.

[8] L. Guerra, D.T. Allen, R.H. Crawford, and C. Farmer, "A unique approach to characterizing the engineering design process" in *119th ASEE Annual Conference and Exposition, San Antonio, TX, USA, June 10-13, 2012*, American Society for Engineering Education, 2012. Available: https://peer.asee.org/20878

[9] C. Lindstrom, *We Are Water Protectors*. New York: Roaring Brook Press, 2020.

[10] National Science Teaching Association, "Access the Next Generation Science Standards by Topic." https://ngss.nsta.org/AccessStandardsByTopic.aspx (accessed Feb 1, 2022).

[11] North Dakota Department of Public Instruction. "K-12 Education Content Standards." https://www.nd.gov/dpi/districtsschools/k-12-education-content-standards (Feb 1, 2022).

[12] North Dakota Department of Public Instruction, *"North Dakota Native American Essential Understandings,"* 2015. Available: https://teachingsofourelders.org/wp-content/uploads/2020/02/NDEssentialUnderstandingslg.pdf (accessed Feb 1, 2022).

[13] North Dakota Department of Public Instruction, "Teachings of our Elders: North Dakota Native American Essential Understandings Project." https://teachingsofourelders.org/ (accessed Feb 1, 2022).

[14] Montana Office of Public Instruction, *"Essential Understandings Regarding Montana Indians"*, 2019. Accessed Feb 1, 2022. [Online]. Available: https://opi.mt.gov/Portals/182/Page%20Files/Indian%20Education/Indian%20Education%20101/essentialunderstandings.pdf

[15] Oklahoma State Department of Education, "Oklahoma Indian Tribe Education Guides." https://sde.ok.gov/tribe-education-resources (accessed Feb 1, 2022).

[16] National Museum of the American Indian, "Native Knowledge 360º Essential Understandings about American Indians." https://americanindian.si.edu/nk360/about/understandings.cshtml (accessed Feb 1, 2022).

[17] J. McTighe and G. Wiggins, *Understanding by Design Professional Development Workbook*. Alexandria, VA: Association for Supervision and Curriculum Development, 2004, p. 31.

[18] S.Y. Yoon, M.G. Evans and J. Strobel, "Validation of the Teaching Engineering Self-Efficacy Scale for K-12 Teachers: A Structural Equation Modeling Approach", *Journal of Engineering Education*, vol 103, pp. 463-485, 2014. Available: https://doi.org/10.1002/jee.20049