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Work in Progress: Lessons Learned from Teaching Culturally Relevant Engineering Design in K–12 Classrooms and Applying Them to Undergraduate Engineering Courses

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Introduction and Background:

This work-in-progress paper describes lessons learned from the first two years of a three-year professional development (PD) research project [1] focusing on culturally relevant engineering design implementation in upper elementary and middle school classrooms in rural North Dakota. This paper highlights how some of the key findings are being implemented into undergraduate engineering courses.

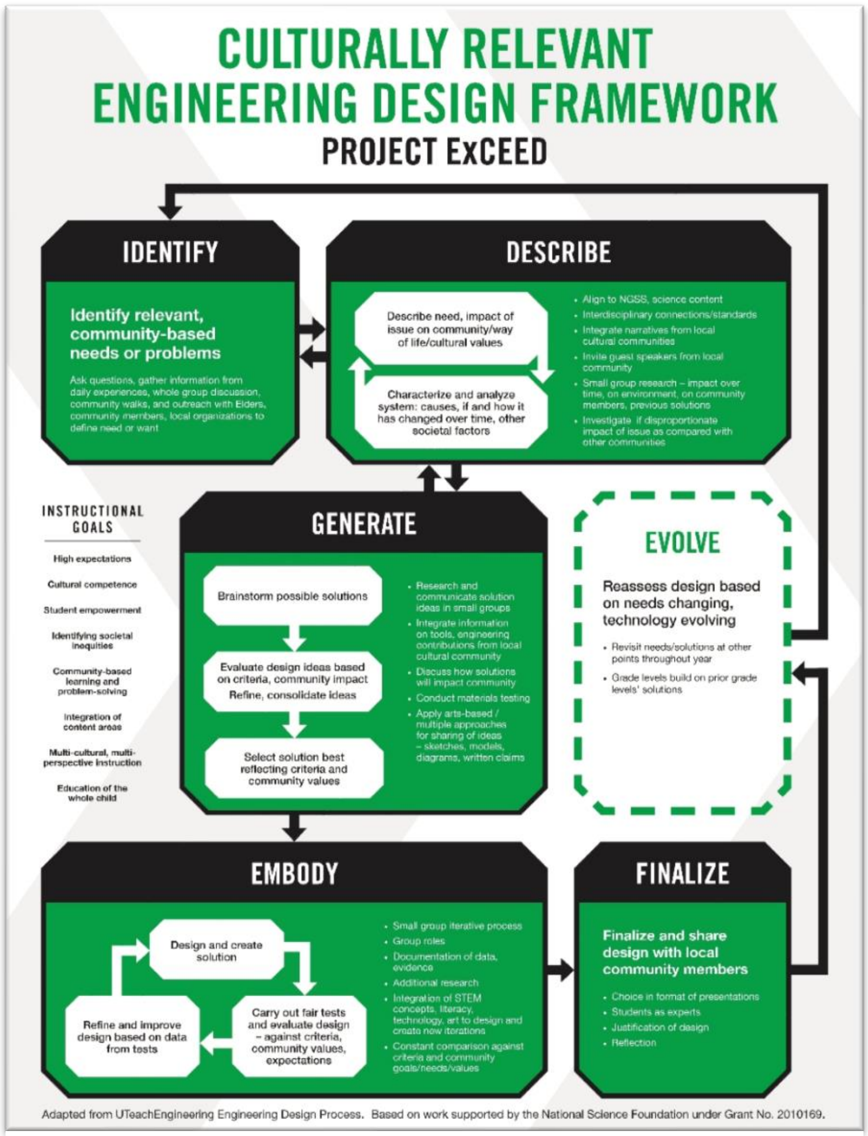

Figure 1: Culturally Relevant Engineering Design (CRED)Framework adapted from [8]

Oftentimes, engineering design tasks within the K-12 and college classrooms are missing cultural and community connections. K-12 teachers are now required to teach engineering design within their curricula due to the adoption of the Next Generation Science Standards [NGSS] into nationwide educational standards [2]. However, teachers do not often possess the engineering self-efficacy and prior knowledge to successfully develop lessons and engineering design tasks. Schools in rural areas and Tribal Nations face additional challenges due to geographical limitations and reduced resources [3]. Within Tribal schools and schools with large Native student populations, the curricula are often presented within a Western framework that typically does not incorporate other cultural and community knowledge, values, and beliefs [4].

Engineering designs, products, and processes do not exist in isolation but are developed and implemented within various cultures and communities. Culturally responsive and culturally relevant teaching principles developed by Ladson-Billings [6] and Gay [7] were used to guide this professional development research project. A primary motivation is to include students' and teachers', family, community, school, and individual experience throughout the PD trainings and within each engineering design task. Within the development of this framework, there have been large successes in relating engineering design tasks to Native American cultural and community values. The culturally relevant engineering design (CRED) framework used within this project, as shown in Figure 1, integrates principles from Ladson-Billings [6] and Gay [7] into the UTeachEngineering Framework [8] to better encapsulate culturally responsive engineering design.

These types of frameworks and pedagogical approaches are becoming more widely used within K-12 education; however, this incorporation of culture and community is not generally adopted for college engineering curricula. One of the primary ways to incorporate students' culture and community is to have students reflect on their own experiences and observations and to have students interview elders and community members so that they can include various viewpoints and information into their design solutions.

Overview of Professional Development and Engineering Design Tasks

Over the last two years, there have been two cohorts of teachers within this research project. Teachers in the program teach grades 3-8 across a range of subjects (Science, Math, English) and work at schools with large Native American populations, located on or near tribal communities in North Dakota. Cohort 1, consisting of 8 teachers from 3 school districts, began in the summer of 2021 with a three-day virtual PD session in June and a two-day in-person session in August. This was followed by an additional three PD days during the 2021-2022 academic year to help teachers further develop and implement three culturally relevant engineering design tasks within their classrooms. Summer 2022 brought in an additional 7 teachers to form Cohort 2 and all PD occurred in person. Within the 2022-2023 PD, teachers from Cohort 1 mentored Cohort 2 participants during both the summer and school year PD days. To collect data on self-efficacy and culturally relevant engineering design implementation several data collection methods were used, including: Teaching Engineering Self-Efficacy Scale (TESS) [9], Culturally Responsive Teaching Self-Efficacy Scale (CRTSES) [10], Culturally Congruent Instruction survey (CCI) [11], qualitative teacher feedback from focus group and individual written and verbal reflections, video recordings of classroom implementation, and lesson plan evaluation with a STEAM scorecard [12]. A more detailed description of the professional development program and engineering design task implementation is described in [13].

Observable Outcomes in Upper Elementary and Middle School Classrooms

From teacher interviews and video observations, one of the largest takeaways from this project is how engaged all students were with their engineering design tasks. Students stayed on task throughout the entire video observation and were engaged with one another and the teacher facilitating the design task. One of the most positive outcomes and themes recorded in group and individual interviews with teachers was that students who normally were not engaged in STEM activities or showed hesitancy towards science or math, were excited and oftentimes led the engineering design task. They were engaged and excited to relate what they had observed in their communities to what they were learning in the classroom. A few quotes from the teacher interviews post-design task implementation are shown below.

> *"The students were really engaged, even more so than last year. Students whose parents worked with water led the discussion. Students loved the Water Protectors book and loved the illustrations. They wanted to do their own book based on the illustrations."*
>
> *"The students had so much fun researching and building their filters. They brought in their own materials, like gravel and aquarium rocks. It was wonderful to watch them learn from exploring, even if their design wasn't perfect."*
>
> *"The kids were really inquisitive, they wanted to try the different materials. They were really curious to see if the mask … to see if it would work."* (The teacher then goes on to describe how one girl in the group was so engaged she snuck out of the room with the mask (a potential filtering device) to try it at the water fountain because the teacher had limited their materials!! The girl was so curious to try it out, she couldn't resist sneaking into the hall to see what would happen...)

From the video observations and individual and cohort interviews it was apparent that when students are able to directly relate what they are learning to their culture and community, it lead to improved engagement and understanding. Reflecting on practices in the chemical engineering curricula, it became apparent that pedagogically college curricula is lacking in this area. There have been great strides to contextualize chemical engineering problems and relate to what our engineering students will be seeing in the future. These types of problems and experiences are vital to helping prepare students for future careers, however especially in first- and second-year engineering courses, more emphasis needs to be placed on relating engineering concepts and problems to our students' culture and community.

Connecting to students' culture and community in the college classroom

While engineering often feels devoid of culture and community, all engineering solutions exist within and for specific communities and cultures. How we bring students' backgrounds into the classroom will vary depending on student demographics and the location of the college or university. Simple methods to engage students' culture and community include: interviews of community, family, and elders; having students relate concepts to things they observe or engineering problems they face daily. Some community scenarios for illustrating engineering concepts/problems that have worked well within the upper Midwest have been: the creation of dams for flood control and hydroelectricity generation, winter heating costs, oil pipelines, and the dangers of predatory credit cards and loans. The following section will illustrate how these examples were used within first- and second-year engineering courses. Along with the insights gained from the K-12 teacher PD research project, these ideas were also based on teachings from a workshop by Northwestern University's Department of Chemical and Biological Engineering Anti-racism, Diversity, Equity, and Inclusion Committee at ASEE's 2022 Chemical Engineering

Summer School [14]. This workshop presented tools and approaches for connecting students' culture and community to the curricula, along with addressing the important issues of anti-racism, diversity, equity, and inclusion within the classroom.

Garrison Dam: When discussing hydrostatic pressure within a sophomore-level fluids unit, the Garrison Dam on the Missouri River in western North Dakota was used as an example to contextualize and relate this concept to one of the home communities of students in the class. Story maps from ArcGIS were used to illustrate the effects on the Mandan, Hidatsa, and Arikara peoples who called this area of the Missouri River home [15]. The students were able to see both the benefits of generating renewable energy alongside the irrevocable harm caused to the MHA Nation. Students were tasked to determine the force acting on the dam, and, using the above resource, to examine social and cultural impacts arising from the flooding of agricultural lands that forced the relocation of several tribal communities within the MHA Nation due to the creation of the Garrison Dam.

Winter heating costs: In a northern climate a large cost to students living off campus can be winter heating. When understanding and learning about conductive heat transfer, students are tasked with estimating the insulation or R-value of their apartment walls and windows by measuring temperature differences across walls and windows and estimating the materials of composition. Using appendices with thermal conductivities of various materials, students estimate how to best reduce heat loss to the surroundings and are encouraged to implement these changes in their off-campus housing. An in-class example problem used in this learning module, looks at the ability to insulate windows with a clear piece of plastic to create an air gap between the window and the heated room. The students are able to estimate that they can save upwards of $20 a month depending on how many windows they insulate. This is a problem that students can directly connect with and relate directly to ways for improving their quality of life. Additionally, conversations on how people who historically resided in the Northern Great Plains helped insulate their homes (using snow, sod, animal hides, etc.) show how innovative Indigenous peoples and homesteaders were able to adapt to this area before indoor heating improvements.

Oil pipeline: One highly contentious issue within the Upper Midwest is the construction and replacement of oil pipelines, most recently the Dakota Access Pipeline and Enbridge Line 3. Most students have some direct experience or knowledge of the protests surrounding these projects, yet often do not have the complete engineering and/or cultural understanding to fully understand the complexity of the issues. Within both an engineering ethics course and a fluids course this topic is discussed. In the fluids course frictional losses due to fluid flow in a pipe are used to introduce the topic, along with the concept that all valves and pipes leak. Ways to mitigate leaks and prevent environmental damages are discussed within the context of the pipeline. The students are asked to relate their experience and background to local lakes and rivers that both pipelines would cross. Experts from pipeline management companies are brought into the classroom to discuss ways they mitigate environmental issues and risks. In the ethics class, students are tasked with comparing and contrasting the safety and ethical considerations of various methods of oil transportation. Within this region, there have been several rail car derailments and explosions, and numerous oil truck-related crashes that students will be familiar with. Students are asked to connect both their individual values and the values of other demographic groups in the affected communities in evaluating the ethical considerations of the various modes of transporting oil out of the region.

Predatory loans and credit cards: When introducing Microsoft Excel to first-year students, a scenario emphasizing the dangers of predatory credit cards and loans is used. The students learn how interest works against them when taking out a predatory credit card, payday loan, or college loan, and how interest can work for them when investing at an early age. Students are asked to interview their parents, friends, and mentors about their experiences with credit cards and investing to see how these concepts have directly impacted those around them. These examples and short life lessons have been positively perceived by students, especially nontraditional students returning to college for a career change. It’s affirming to see discussion board posts and emails stating how relating this directly to their own experiences and showing concern for their financial well-being helps students master and learn Excel in an engaging way. These same concepts and Excel techniques are also used during the economic analysis of a large chemical process in senior plant design, however, it's more impactful to relate these concepts to students’ current financial situation as occurs within the first-year course.

Lessons Learned and Future Implementation

Increased engagement and understanding of complex engineering concepts can be achieved at all educational levels when students can relate to their lived experiences, culture, and community. Within the college curricula, it is imperative that instructors take the time to get to know their classroom demographics and determine the best way to relate concepts to students’ cultures and communities. One way to make these connections is by rooting concepts and classroom examples into the geographic area of the University and its students. Future implementation of this work will include weekly homework problems or case studies within the sophomore and first-year classes that engage students’ community and cultural connections along with continuing to give space for students to reflect and ask questions to their communities and families relating to engineering concepts and solutions.

References:

[1] "Project ExCEED, Exploring Culturally relevant Engineering Education Design" https://sites.google.com/nescnd.org/projectexceed/home (accessed Apr 14, 2023)

[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] 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

[10] K. O. Siwatu, "Preservice teachers' culturally responsive teaching self-efficacy and outcome expectancy beliefs." Teaching and teacher education 23, no. 7, pp 1086-1101. (2007)

[11] R. Sievert, J. LaFrance, and R. Brod, "Development, Validation, and Preliminary Use of the Culturally Congruent Instruction Survey," *American Educational Research Association National Conference*, 2011.

[12] "NYU Steinhardt," *Culturally Responsive Curriculum Scorecard*. [Online]. Available: https://steinhardt.nyu.edu/sites/default/files/2021-02/CRSE-STEAMScorecard_FIN_optimized%20%281%29.pdf. [Accessed: 26-Jan-2023]

[13] Prior ASEE publication (will be added in final paper)

[14] "ARDEI -Context Question Writing Workshop," *ARDEI Context Question Writing Workshop*. [Online]. Available: https://sites.northwestern.edu/ardeiquestionworkshop/writing-an-ardei-context-question/. [Accessed: 26-Jan-2023]

[15] C. Griffith, “Before & after the Flood,” *ArcGIS StoryMaps*, 08-Aug-2022. [Online]. Available: https://storymaps.arcgis.com/stories/b2157f19173a4495bd7b6c0d2a960528. [Accessed: 09-Jan-2023]