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Teachers' Perceptions on Culturally Relevant Engineering Design: Reflections from Professional Development

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Teachers' Perceptions on Culturally Relevant Engineering Design: Reflections from Professional Development

Abstract

This qualitative study explores teachers' perceptions of culturally relevant engineering design (CRED) through professional development (PD) that is the first phase of Project ExCEED (Exploring Culturally Relevant Engineering Education Design). The data were collected from nine participants from three public schools in North Dakota. The findings shed light on participants' understandings of CRED, Next Generation Science Standards (NGSS), the engineering design cycle and determine how PD influences their views about CRED tasks. The findings suggest that the teachers perceive CRED tasks as authentic, sensitive to students' needs, and modifiable to cross-curricular contents. The results of this study suggest that PD has a positive influence on participants' culture-specific and engineering design knowledge, participants' confidence with regards to implementing CRED and thinking beyond the classroom.

Purpose

The National Academy of Engineering's 2004 report highlighted the need for effective solutions for underrepresented and minority populations in the engineering workforce for 2020 projections. Although the share of science and engineering degrees awarded to minorities has increased in the past decade, minorities are still underrepresented compared to their population in the U.S. (National Center for Science and Engineering Statistics [NCSES], 2021). In addition, students who come from underrepresented and racial minority groups often feel "solo" due to lack of diversity in the STEM programs or lack of confidence about their preparedness when they are successful in their programs (Hurtado et al., 2010).

Native Americans are the most underrepresented minority population at all levels of education (Fore & Chaney, 1998), particularly in engineering degrees (American Society for Engineering Education [ASEE], 2016). Williams (2014) reported that American Indians represent 1.2% of the total U.S. population; however, they only received 0.3% of all doctorates in 2012). There were only 48 research doctorates who were American Indian /Alaska Natives in science and engineering fields in 2012 among 11,764 Ph.D. recipients who had U.S. citizenship and permanent residency (Williams, 2014). According to ASEE (2016), American Indians or Alaska Natives had the lowest persistence rates in undergraduate engineering programs with only 73% persisting to the second year in 2004. In contrast, this rate was 82% for White students, 87% for Asian Americans, 75% for Black or African Americans, and 76% for Latino or Hispanic students (ASEE, 2016).

Encouraging students into science and engineering at earlier stages of education is essential regarding students' science career interests (Tai et al., 2006). To close the STEM educational gap (National Science Board, 2010), elementary and middle school teachers need to be supported (Augustine, 2005), particularly in teaching engineering (Committee on K–12 Engineering Education, 2009). Providing high-quality PD for teachers plays a critical role in increasing student STEM interests and increasing representation in the STEM workforce (Miles et al., 2015). While there have been efforts to provide STEM-focused PD for teachers in recent years (Brenneman et al., 2019; Hammack et al., 2020; Nadelson et al., 2013; Nesmith & Cooper, 2019), there is limited guidance and teacher PD available related to engineering for elementary school teachers (Committee on K–12 Engineering Education, 2009).

Culturally relevant pedagogy (CRP) is a social-justice framework (Allen et al., 2017) that integrates culture into education. The main focus of CRP is to increase students' academic success, cultural competence, and critical consciousness (Ladson-Billings, 1995). CRP is an effective way to promote inclusive culture in STEM departments (Johnson & Elliott, 2020) that can be used to reduce disparities and increase underrepresented students' access to science education (Patchen & Cox-Peterson, 2008). Culturally responsive teaching (CRT), developed based on CRP, is a student-based and multidimensional approach that incorporates students' cognitive performance and supports moral, social, cultural, and political development (Gay, 2018). Although there are expectations for teachers to use CRT, in practice, it is not easy to change their pedagogy without providing opportunities for them to reflect on their beliefs and identities (Leonard et al., 2009). Teachers may have difficulty explaining the rationale of the practices in bicultural or multicultural settings and reaching a collective understanding of integrating CRT into their classrooms.

The lack of empirical studies relevant to the integration of CRP into engineering design is a barrier to making engineering content more accessible for diverse learners. Most studies in the current literature relevant to CRP focused on underrepresented groups such as African Americans and Latinos. Native American populations have not been frequently studied in the literature dealing with ethnic identity and student achievement (Whitesell et al., 2009). In addition, elementary and middle school teachers struggle with teaching engineering due to a lack of engineering content knowledge and limited guidance about Next Generation Science Standards (Committee on K–12 Engineering Education, 2009).

Project ExCEED (Exploring Culturally Relevant Engineering Education Design) is funded by the National Science Foundation (NSF) and includes three aspects: 1) Summer Institute, 2) Cohort Meetings throughout the school year, and 3) Culturally Relevant Engineering Design (CRED) tasks that teachers implement in their classrooms. Using Bandura

(1977, 1982)'s Social Learning Theory and CRP, Project ExCEED was designed to improve elementary and middle school teachers' engineering design self-efficacy through ongoing, collaborative and culturally-relevant PD.

The present study explores teachers' understandings of CRED and how PD influences their views about implementing CRED tasks in their classrooms. The following research questions were examined:

1. How do elementary and middle school teachers perceive and experience CRED?
    1.1. What do elementary and middle school teachers reflect on when learning to teach CRED?
2. How does culturally relevant PD influence teachers' views related to CRED tasks?

Theoretical Framework

Culture has a strong impact on our thinking, belief systems, communication, and behavior (Gay, 2018). It reflects authentic ways of learning, knowing, understanding the world, and solving problems (Spang & Bang, 2014). Teaching science with a dominant Western paradigm is an important reason for high dropout rates and underachievement among Native American students (Nelson-Barber & Estrin, 1995). Native views of knowing science have unique features compared to the Western paradigm (Roehrig et al., 2012). While natural phenomena in the Western Eurocentric approach are situated in objective scientific facts obtained via observational and experimental methods, Native ways of knowing are more intuitive and spiritual (Nelson-Barber & Estrin, 1995).

The Project ExCEED PD program was aligned to the NGSS (NGSS Lead States, 2013), North Dakota Native American Essential Understandings (NDNAEU) (North Dakota Department of Public Instruction, 2015), and North Dakota Science Content Standards Grades

K-12 (North Dakota Department of Public Instruction, 2019). With the guiding principles of social learning theory and CRP, teachers are able to understand Native American students' learning styles, cultural identity, and how Native American students' culture is naturally integrated into engineering in their lives.

Method

This qualitative, exploratory, and descriptive study addresses PD participants' understandings about CRED and how PD changes their views in pre and post sessions. To explore this, we analyzed focus group interviews, individual and cohort written and verbal reflections, interactive online PD activities, video recorded PD sessions, and researcher field notes. This paper uses data from Project ExCEED virtual PD sessions conducted during June 2021 and in-person PD sessions conducted in August 2021.

Participants

This study included nine participants (eight elementary and middle school teachers and one administrative staff) from three public schools in North Dakota who attended Project ExCEED PD sessions in Summer 2021. The majority of the participants are white and female. All PD participants have different levels of teaching experience and educational expertise. Demographic information for all participants is presented in Table 1.

Project ExCEED Professional Development

The learning modules of the Project ExCEED PD program were developed by the Project ExCEED team members, Native American tribal members, education specialists, and STEM experts. The main goals of the Project ExCEED summer PD program were to increase teachers' knowledge about engineering design and CRP and to provide support to the teachers to prepare them for CRED implementations in fall 2021. The PD consisted of the following focus areas: Foundational understandings of NGSS and their alignments with ND Science Standards, the engineering design process, culturally relevant instruction, and NDNAEU.

The PD sessions provided opportunities for participants to discuss the CRED themes including local water quality issues in specific communities with local community members, experts, and elders. A collaborative hands-on CRED activity was the center piece of the June PD session. The June PD (virtual sessions) also included interactive and small group activities about CRED stages and identifying relevant resources. The August PD (in-person sessions) focused on identifying standards from NGSS that align at different grade levels, introduction to an engineering aligned UbD framework, small group working sessions on the CRED framework, and discussions on sustainability of the outcomes. During the PD sessions, Project ExCEED team members collaborated with PD participants to develop student-friendly version of the CRED framework (See Appendix A). The purpose of this student-friendly version is to provide essential information on CRED in a format accessible to students and stakeholders.

Data Sources

The first set of PD data was collected from the 3-day Project ExCEED virtual PD sessions in June 2021. The second set of PD data was collected from the 2-day in-person PD session in August 2021.

Focus Group Interviews. Semi-structured and open-ended questions were used to gather information from the PD participants. Each focus group consisted of three to five teachers. The focus group interviews were conducted by the Project ExCEED team members. Some of the focus group interview questions from the first PD session were as follows: “How do you incorporate students’ culture into your classroom?”, “What are the challenges you face in meeting the needs of all of your students? What supports do you feel you need?”. The second

PD session included the following focus group interview questions: “What are some of your biggest take-aways from the PD from both the June and August sessions?”, “What aspects about the design and implementation of the PD worked for you?”, “In what ways do you think your teaching practice will be impacted?”

Documents, Field Notes, and Artifacts. The other data sources include individual and cohort verbal and written reflections, collaborative and interactive online PD activities, video recorded PD sessions, and the researchers’ field notes from small group activities.

Data Analysis

Braun and Clarke’s (2006) framework of thematic analysis was used for qualitative explorations of PD data. Thematic data analysis is a data analysis method that identifies, organizes, and organizes patterns from the data (Braun & Clarke, 2012). Both top-down (driven by research questions) and bottom-up (data-driven) approaches were used (Maguire & Delahunt, 2017) for data analysis. Open coding was used to create initial codes, and preliminary themes and codes were developed by the members of the Project ExCEED team.

Findings

The following themes were identified from the first session of the PD program data: “CRED,” “pedagogical approaches,” and “expectations.” The second part of the PD data included “perceived benefits”, perceived challenges”, and “expectations” themes. Subthemes within each of the primary themes were also identified and reported separately for each PD session in Table 2 and Table 3, respectively.

Culturally Relevant Engineering Design Tasks (CRED)

This theme illustrated that CRED was student-centered, sensitive to students’ needs, authentic, and helped teachers to understand their students’ backgrounds. Some of the teachers stated that CRED tasks could be integrated into cross-curricular content such as English language arts and social studies. They also found reflective practice and collaboration with other participants very helpful when learning to teach CRED and that it improved their awareness about CRP and content knowledge in engineering design.

The PD participants (as groups) were asked to find connections between the CRED framework and the mindset of culturally responsive educators (MCRE). Sociocultural consciousness, high expectations, desire to make difference, constructivist approach, deep knowledge of their students, and culturally responsive teaching practices (Ontario Schools, Ontario Human Rights Commission, 2013) were presented as six core aspects of MCRE in this PD activity. Further information about culturally responsive educators can be found in the textbook “Culturally Responsive Teaching: Theory, Research, and Practice” written by Geneva Gay in 2018. The frequency table of the cohorts’ reflections is presented in Table 4. According to the findings, the identify and describe stages of the CRED framework have critical importance with regard to the MCRE.

Pedagogical Approaches

One of the aspects related to the pedagogical approach theme is grade level. The PD participants indicated that younger students needed more structured CRED tasks than their older counterparts. They also mentioned that CRED tasks might be an advantage for students who like to collaborate with their peers and that could help to improve student communication skills and classroom atmosphere. In addition, participants described that teaching with CRED would allow students to be creative and for students to have more freedom about CRED tasks, particularly at the middle school.

Perceived Benefits

One of the themes that emerged from the second part of the PD session was perceived benefits. The PD participants indicated that the first-hand experiences like sessions with local experts and elders were helpful in terms of improvement of their understanding of the CRED framework. They highlighted that they had a clearer vision and confidence regarding the implementation of CRED. One PD participant underscored that PD was helpful regarding thinking beyond the classroom, including building sustainable community connections at a large scale.

Perceived Challenges

The PD participants indicated that they needed more processing time to understand the implementation of the CRED framework in cross-curricular contexts. The PD participants also highlighted that one of the challenging parts for them before attending the second PD session was understanding the big picture and purpose regarding cultural and community connections.

Expectations

The PD participants indicated that implementing CRED might be time-consuming in teaching process. Some of them underscored that they want to gain insights on finding new ways to integrate culture into engineering, have more collaboration opportunities with the other teachers in the cohort, and more guidance on where to fit the lesson plans into their current and future curriculums. Finally, they also stated that they need time to process the connections between NGSS, ND Science Standards, NDNAEU and CREDF.

Significance of the study

This study helps to address teachers' perceptions about CRED that will improve teaching engineering practices in a meaningful and effective way, detect potential challenges in the implementation process of CRED, and promote equity for underrepresented and minority students with respect to engineering. The results show that PD has a positive influence on participants' confidence to incorporate culture into engineering and implement CRED in the classroom. Participants identified meaningful connections between the CRED framework and MCRE.

Table 1

Demographic Characteristics of the Professional Development Participants

Participants Code	Gender	Ethnicity	Highest Degree Received	Grade Levels Teach	Subject	Years of Teaching Experience
P1	F	White	Master's Degree	7-8	Science	1-5
P2	M	White	Bachelor's Degree	4-5-6-7-8	Business/ Computers	1-5
P3	F	NA, White	Master's Degree	8	ELA	6-10
P4	F	White	Bachelor's Degree	4-5	Science	11-15
P5	F	White	Master's Degree	4	Science, Math, ELA, SS	16-20
P6	F	White	Bachelor's Degree	5-6	Science	1-5
P7	F	White	Bachelor's Degree	5	Science, Math, ELA, SS	11-15
P8	F	White	Master's Degree	6	ELA, SS	6-10
P9	F	White	Bachelor's Degree	1-3-4-5-6, SN	Math, ELA	More than 25

Note. F= female, M = male, NA = Native American, ELA = English Language Arts, SS = Social Studies, SN = special needs

Table 2

Themes and Subthemes of the Project ExCEED June 2021 PD Data

CRED	Pedagogical Approaches	Expectations
Student-centered	Sensitive to students' needs	Time
Cross-curricular	Grade Level	Insights
Collaborative	Classroom atmosphere	Ways to cultural integration
Reflective practice	Creativity	
Types of the activity (hands-on)		
Culturally relevant resources		

Note. CRED = culturally relevant engineering design

Table 3

Themes and Subthemes of the Project ExCEED August 2021 PD Data

Perceived Benefits	Perceived Challenges	Expectations
Improvement in understanding CRP in engineering	Integrating CRP into a cross-curricular discipline	Excitement and engagement of students
Thinking beyond the classroom	Need more processing time	Improvement in current practices
Increased confidence in teaching CRED with the student-friendly version of CRED framework	Big picture/ purpose	More collaboration with other teachers in the cohort
Clearer vision in CRED implementation	Finding ways to do better in implementations	Need more guidance on where to fit the lesson into their current and future curriculums
First-hand experiences		

Note. CRED = culturally relevant engineering design, CRP = Culturally Relevant Pedagogy

Table 4

Frequency Table of the Cohorts' Reflections to Relationship between steps in the CRED framework and MCRE

MCRE \ CRED framework	Identify	Describe	Generate	Embody
Sociocultural consciousness	XX	XX		
High expectations	X	X	X	
Desire to make a difference	XX	X		X
Constructivist approach	X	-	XX	XX
Deep knowledge of their students	XXX	XX	X	X
Culturally responsive teaching practices	X	X		XX

Note. CRED = culturally relevant engineering design, MCRE = mindset of culturally responsive educators, X = represents the "1" response from each cohort.

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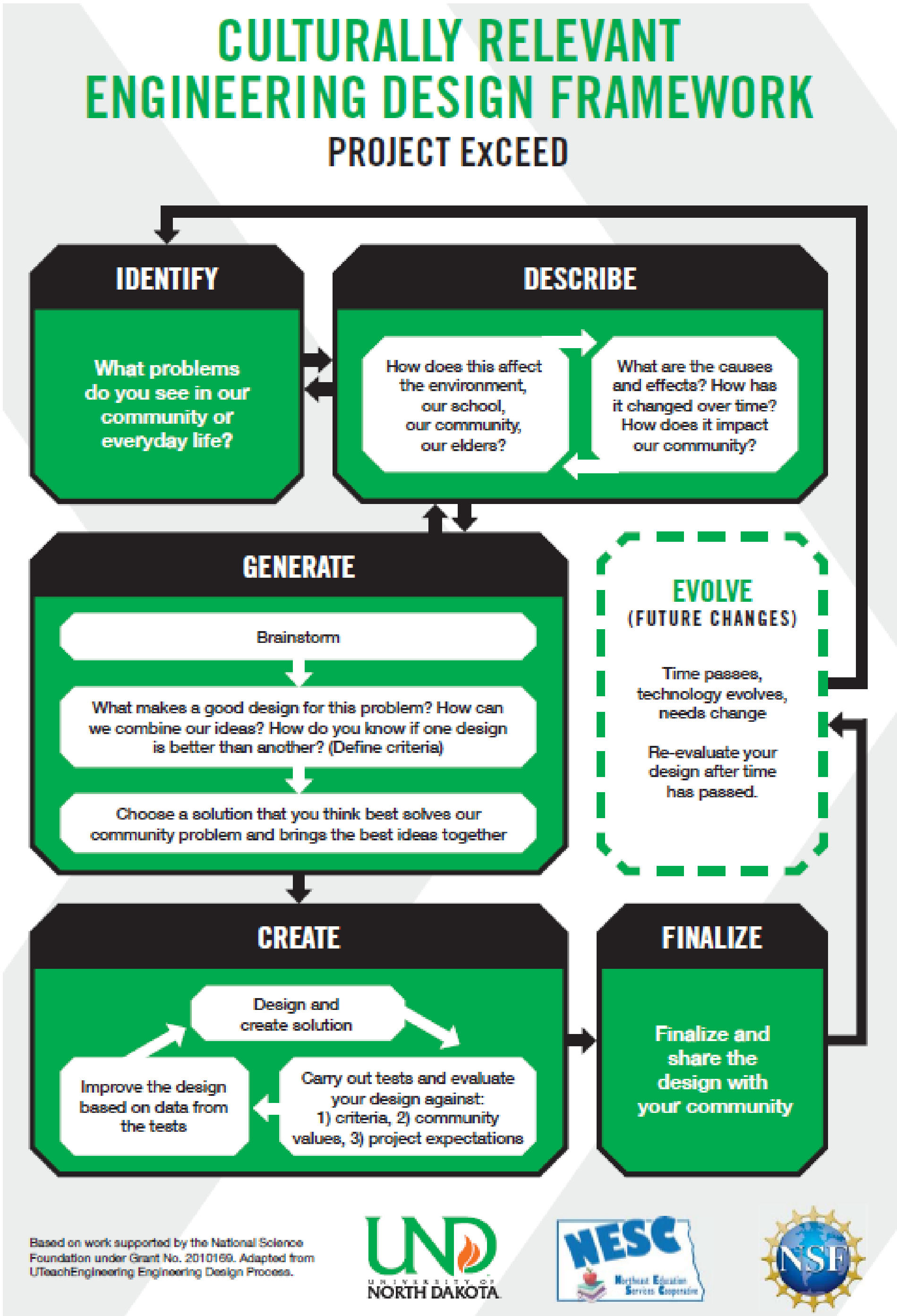
Appendix A

Culturally Relevant Engineering Design (CRED) Framework



Note. Adapted with permission from Understanding by Design Professional Development Workbook™ (p. 31), by J. McTighe and G. Wiggins, 2004, Alexandria, VA: Association for Supervision and Curriculum Development.