Exploring the Design and Delivery of Community Relevant Engineering Design in Elementary and Middle School Classrooms (RTP)

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Abstract

A growing body of research and curricula, and the NGSS, highlight the importance of students engaging in engineering education that is relevant to their lives, situated meaningfully within their communities and cultures, and aligned to their interests and values for deeper learning and engagement [1], [2]. Centering engineering problems within students' lived experiences and epistemologies amplifies the social, interactive, and contextualized nature of engineering in the classroom, increasing student access to engineering practices, knowledge, and problem scope [3], [4].

To implement community relevant engineering education, teachers require sufficient professional learning (PL), yet research is still exploring how teachers learn to teach engineering in PK-12 classrooms and the purpose and features of engineering they then implement [5], [6]. As part of an NSF-funded project, we conducted a two-year PL for 15 elementary and middle school teachers using a Community Relevant Engineering Design (CRED) Framework [7] to develop their self-efficacy and instructional practice with implementing community relevant engineering design. This qualitative study explores how four of those teachers applied the research-based CRED principles presented in the PL to their engineering lesson design, classroom implementation, and practice.

Research Questions:

1. How do teachers design and implement community relevant engineering design in their classrooms in response to on-going PL?
2. What key instructional features and strategies of a community relevant approach to engineering education are most emphasized or adapted in teachers' lesson design and implementation?

Over the two-year PL, teachers developed and implemented six CRED-aligned engineering tasks in their classrooms, participating in on-going learning that emphasized strategies for connecting engineering to local contexts and best practices in engineering instruction and culturally relevant pedagogy. Teachers recorded themselves teaching their CRED tasks and reflected on their teaching experiences through individual interviews. Data sources for this study include teachers' lesson plans, 30-minute video recordings of classroom lesson implementation for each teacher, and transcripts of their 30-minute reflective individual interviews from the first year of the project. Video data were analyzed using a modified version of the Classroom Observation Protocol for Engineering Design (COPED) [8], focusing on types of teacher and student interactions and elements of community and culturally relevant pedagogy within each CRED stage. Content analysis [9] was used to analyze their lesson plan design, content, and interview transcripts to identify themes in relation to the CRED principles.

Results suggest that lesson design, content, and instructional practices all evolved over a year of PL. Notable CRED principles applied in the classroom included increased connection to community and culture through community partnerships, contextualization of tasks within local issues, and direct application to students' lives and families. Shifts in instructional practice included increased student choice, autonomy, and discourse within the engineering tasks. Our findings provide implications for how community relevant engineering design is enacted in the classroom as a result of PL, the key principles teachers bring to their classrooms, and what we understand about teachers' learning and application of community relevant engineering education.

1. Introduction

Research, curricula, and the Next Generation Science Standards (NGSS) highlight the value of engineering education that connects meaningfully to students' lives, communities, and cultures [1], [2]. Centering engineering problems within students' lived experiences creates more authentic engagement with engineering practices in the classroom and helps students access engineering knowledge and problems more equitably. [1], [3]. However, teachers need substantial professional learning (PL) to effectively implement this type of community relevant engineering education, and research is still exploring how PK12 teachers learn to teach engineering and what aspects of engineering they implement in their classrooms.

As part of an NSF-funded project, we conducted a two-year PL for 15 elementary and middle school teachers using a Community Relevant Engineering Design (CRED) Framework [7] to develop their self-efficacy and instructional practice. This qualitative study explores how a set of four teachers applied the research-based CRED principles presented in the PL to their engineering lesson design, classroom implementation, and practice. Study design and analysis were guided by the following research questions:

- How do teachers design and implement community relevant engineering design in their classrooms in response to ongoing PL?
- What key instructional features and strategies of a community relevant approach to engineering education are most emphasized or adapted in teachers' lesson design and implementation?

Our findings demonstrate how community relevant engineering design evolved in classroom settings during the two-year PL, identifying which principles teachers emphasized most strongly, and what these patterns reveal about teachers' learning and application of community relevant engineering education.

2. Background

Engineering in Elementary Classrooms

The adoption of new science standards at the state level and internationally has called for increased integration of engineering content, skills, and knowledge within science curriculum. This paradigm shift is notable particularly in states who are using or have adapted the Next Generation Science Standards (NGSS), which emphasize the importance of engineering education for increasing relevance, access, and application of content across disciplines and for a greater diversity of students [2]. To effectively implement engineering education in PK-12 classrooms, all teachers need PL in understanding the discipline of engineering as well as best practices in designing and teaching engineering lessons that move beyond simple building activities into curriculum that authentically applies science, technology, and math concepts as well as real-world issues. In doing so, students see the purpose of engineering as solving problems and improving societal conditions, thereby increasing their engagement, learning, and sense of belonging, and fostering greater potential for STEM education and workforce trajectories. Further, this shift supports the development of invested and literate citizens [2], [5], [10], [11]. Engineering education is vital for providing relevant and real-world contexts for interdisciplinary learning. Literature suggests that meaningful engineering education for students at all levels includes direct experience working with the engineering design process (EDP), allowing them to engage authentically in engineering practices, to apply other disciplines across the stages of the EDP, and to design and optimize solutions based on evidence and real-world constraints [5], [10], [11]. Yet without sufficient training for teachers to build their engineering background and disciplinary knowledge, they may be less likely to devote equal time, scaffolding, and resources to each stage of the EDP, often limiting students' participation in the problem-scoping, identification, and information-gathering stages and focusing more on the planning and embodiment phases [12], [13]. This limited and often isolated professional learning for teachers, particularly at the elementary level, results in low self-efficacy and limited preparation for teaching engineering, which can contribute to decontextualized or superficial implementation of engineering tasks that lack connection to students' lives or experiences [5], [14]. Further, existing models of professional learning rarely present engineering as a knowledge-building endeavor [13], nor do they delve into current understandings and frameworks of the nature of engineering.

Nature of Engineering

Limited PL in engineering, both in availability and scope, may be due to still-developing conceptions of the nature of engineering (NOE) broadly. While a vast body of research has described the nature of science and its translation into classroom curriculum and instruction, less has been developed with regard to NOE and to how teachers' conceptions of engineering are shaped by their beliefs about both the engineering discipline as well as engineering pedagogy and instruction [15]. Embedding NOE into classroom instruction has direct applications for supporting the three-dimensional approach to science and engineering education emphasized by NGSS [2] with a focus on the integration of Disciplinary Core Ideas, Cross-Cutting Concepts, and Science and Engineering Practices [16]. Yet a lack of consistency among NOE frameworks as well as the variation in EDP representations may impact agreement in what engineering skills and concepts are considered important to be taught in classrooms and the purpose and approach that is incorporated into PL [17].

NOE refers to understandings about what engineering is, its purpose, the profession and role of engineers and what they do, and the ways in which engineering applies disciplines such as science, technology, and math for societal benefits, with these definitions varying across frameworks [4], [17], [18]. While NOE conceptions tend to draw parallels to aspects of nature of science (NOS), these comparisons are not directly transferable, resulting in misrepresentations and gaps in NOE descriptions [18].

Deniz et al. [4] reviewed the literature exploring different aspects and framings of NOE, as aligned to NGSS [2] and the [16] and identified the following components in their synthesis across the body of research: (a) demarcation (what engineering is and what distinguishes it from other disciplines); (b) the engineering design process; (c) empirical basis (the use of evidence to optimize designs); (d) tentativeness (design solutions are subject to change); (e) creativity; (f) subjectivity (there are a range of solutions dependent on conditions and constraints); (g) social aspect of engineering (engineering is conducted through social negotiation); (h) social and cultural embeddedness (engineering and society constantly interact); (i) criteria/constraints (engineers work within predetermined parameters); and (j) failure-laden (failure is an inevitable part of engineering to improve designs). Through this lens, they discussed that these characteristics should be directly taught within classrooms through an "explicit-reflective" approach, in which students experience and reflect on the specific components of NOE and consider their developing understandings about engineering over the course of their engagement with engineering design tasks and through the EDP [4]**.**

Teachers' conceptions of NOE shape their self-efficacy and preparedness to teach engineering and curate curricular materials effectively [15], [19]**.** Despite limited research in best practices to support teachers' implementation of engineering, studies do suggest that PL which focuses on the EDP, directly teaches aspects of the NOE, and allows educators to engage directly with engineers, engineering tasks, and engineering content impacts their understandings about the discipline of engineering, the EDP, and integration of other disciplines into the field [18], [20], [21], [22]**.** According to Sung and Kelly [23], in K-12 engineering education, the engineering design process (EDP) guides students and educators in engineering learning, and the characteristics of engineering design include iteration and collaboration, the co-evolution between problem and solution domains, complex cognitive processes, reflective decision-making, dealing with "wicked problems" and learning through failure.

Community Relevant Engineering Education

A key characteristic of NOE, and one that differs from descriptions of NOS, is a clear connection to context and societal values and constraints [4]**.** Common across NOE frameworks is the subjective and socio-cultural nature of engineering; in other words, engineering solutions are designed and negotiated within a specific community context and through continuous social interactions [4]. Engineering education, therefore, has the potential to leverage this community-based approach by embedding and building from students' experiences, knowledge, and local assets [3]**.** The *Framework for P12 Engineering Learning* [1] emphasizes the importance of connecting engineering lessons and learning experiences to students' lives through several of its guiding principles. By "striving for authenticity", [1, p.15], for example, the framework discusses that tasks should represent authentic engineering practices and processes so that students are being exposed to accurate representations of the purpose and nature of engineering as a discipline within relevant situations. The framework also discusses, as an additional principle, that engineering education must "connect to student interests, culture, and experiences" [1, p. 17], as a way to make engineering learning relevant to students' lives, to remove barriers to their participation, and to increase their sense of personal connection to engineering concepts, knowledge, and practices.

Centering a community relevant approach to engineering not only aligns to conceptualizations of NOE but supports an increased focus on the stages of the EDP. By developing engineering learning experiences that are directly tied to community issues, context, and students' lives, students are encouraged to identify relevant interests in their community and delve more deeply into researching and describing them, which supports greater attention to the often over-looked problem-scoping phases in the EDP [24], [25]. Moreover, the community context creates a more intentional purpose to the activity for students to align to local values and characteristics and understand how their solutions might impact a specific community [11]. When community is embedded throughout the stages of the EDP, students can engage with historical information, interview community partners, and even present their design solutions to a broader community audience [26]. These purposeful and relevant connections, enhancing students' understanding of NOE and the EDP, increase student engagement and thus broaden pathways for more students into STEM education and workforce pathways.

Teachers' training in and implementation of community relevant engineering

While studies show that teachers across grade levels often have low self-efficacy and feel unequipped to teach engineering [7], [14], [27] scant research has described how to best prepare educators to teach engineering, particularly with a community relevant focus [5], [28]. In general, curricula and professional development often fail to emphasize the role of place and community, and this is even more pronounced within engineering education and PL [29]. Studies that do explore community relevant engineering PL tend to focus on its impact on teachers' self-efficacy rather than transformation to lesson design or implementation. Gunning and colleagues [27] noted that a focus on community connection and social justice within an on-going STEM professional learning program increased participants' reflection and awareness of multicultural approaches to engineering. In a case study conducted by Boz and colleagues [30] the incorporation of community exploration and an ethnographic approach within engineering PL increased the teacher's integration of community-based opportunities and connections within her engineering lesson design and implementation. Finally, Bowman et al. [7] found that after engaging in on-going PL focused on community relevant engineering design, preliminary data showed teachers using greater intentionality with connecting to students' lives, cultures, and with community partners. While these few studies show promising results from PL that incorporate a community relevant approach to engineering, understanding remains limited about the ways in which teachers subsequently design and implement community relevant engineering lessons and the key features that emerge in their instruction as a result.

3. Theoretical Framework

Our study is guided by the interwoven concepts of self- efficacy at the core of Bandura's Social Learning Theory [31] which suggests that people learn new behaviors, attitudes, and knowledge by observing and imitating others, Culturally Relevant Pedagogy (CRP) which aims to promote academic success, cultural competence, and critical consciousness among diverse student populations [32] and emphasizes culturally responsive teaching (CRT) to make learning more relevant and effective for diverse students [33]. Teacher's self-efficacy in any content area is a strong predictor of student motivation and learning outcomes, particularly in STEM domains, where teachers' perceptions of their own knowledge directly affect their instructional effectiveness [34], [35].

According to Bandura [31], self-efficacy refers to an individual's belief in their capacity to execute behaviors necessary to produce specific performance outcomes. Bandura argued that personal efficacy determines whether one will attempt to perform an action, and for how long one can persevere in coping with obstacles and challenges. Bandura suggests that individuals who have a high level of self-efficacy are more likely to engage and persevere in achieving objectives, people tend to avoid situations in which they have low self-efficacy, and individuals' beliefs in their efficacy are developed by four primary sources: (i) enactive mastery (past performance accomplishments resulting from previous experiences or training), (ii) vicarious experience (observing a role model succeed in a particular area raises the observers' beliefs that they too possess the capabilities to master comparable activities to succeed), (iii) social/verbal persuasion (persuasion through collaboration or from obtaining positive and encouraging feedback from role models can help overcome self-doubt), and (iv) psychological arousal (from own responses including changes in emotional states such as anxiety, fear, or positive anticipation. Bandura [31] emphasized that self-efficacy is highly context dependent. Therefore, a person's self-efficacy is a strong determinant of their effort, persistence, and strategizing, as well as their subsequent training and job performance, and self-efficacy is context-dependent - it is how effectively an individual will perform a given task, which is different from the person's self-confidence or their self-esteem [36]. Also, Heslin & Klehe, 2006 [36] argued that there is no single standardized measure of self-efficacy and measures need to be developed to gauge an individual's capacity to either (a) achieve a certain outcome on a particular task (outcome self-efficacy), or (b) engage in the processes likely to lead to a certain, desired outcome (process self-efficacy). Researchers consider enactive self-mastery (performance accomplishment) to be the most effective way of creating a strong sense of efficacy [31], [36], [37], [38] followed by role-modeling, and then verbal persuasion.

Furthermore, Palmer [39] argued that it is necessary to integrate a variety of mastery and vicarious experiences in methods to support the development of teachers' engineering self-efficacy, that sources of teachers' self-efficacy in a course should be determined on a case-by-case basis, and that although a teacher's high efficacy in a course is a necessary requirement for effective teaching, it does not necessarily result in effective teaching, and other factors that influence effective teaching need to be investigated. In addition, some researchers have emphasized that contextual factors such as school culture, colleagues, and administrative support could influence teachers' self-efficacy, and there is a need to examine self-efficacy within specific domains rather than relying on general self-efficacy measures. Therefore, sources of self-efficacy can help elementary and middle school teachers build confidence in teaching engineering design, especially when incorporating community relevance.

According to Sung and Kelly [40] in K-12 engineering education, the engineering design process (EDP) guides students and educators in engineering learning, and the characteristics of engineering design include iteration and collaboration, the co-evolution between problem and solution domains, complex cognitive processes, reflective decision-making, dealing with "wicked problems" and learning through failure.

4. Conceptual Framework

CRED Framework

Our PL model provides a guide for teachers to incorporate the tenets of Community Relevant Pedagogy, and the North Dakota Native American Essential Understandings as essential components of the engineering design process through the use of our Community Relevant Engineering Design (CRED) Framework [Figure 1], and supported teachers in developing their individual and collective self-efficacy in the domains. As shown in Figure 1, the CRED framework, adapted from Guerra *et al.*'s [41] engineering design process, explicitly includes connections to community, culture, and place, with descriptions of how each stage (*Identify* - identification of the problem, *Describe*- Describe the impact of the problem on community, *Generate*- Brainstorm and evaluate ideas to solve the problem, *Embody* - Design solution to the problem, test and improve design, *Finalize* - finalize the design to the problem, and share the design solution), directly addresses community-situated engineering needs and the instructional moves that ensure it is situated within a community and culturally relevant framework. Using the CRED framework as a guide, teachers designed community relevant engineering tasks by first examining their required content within the context of state standards to identify appropriate placement of engineering design tasks in their curricula. Teachers then considered issues that were relevant to their school communities to identify authentic areas of need that students could explore through engineering.

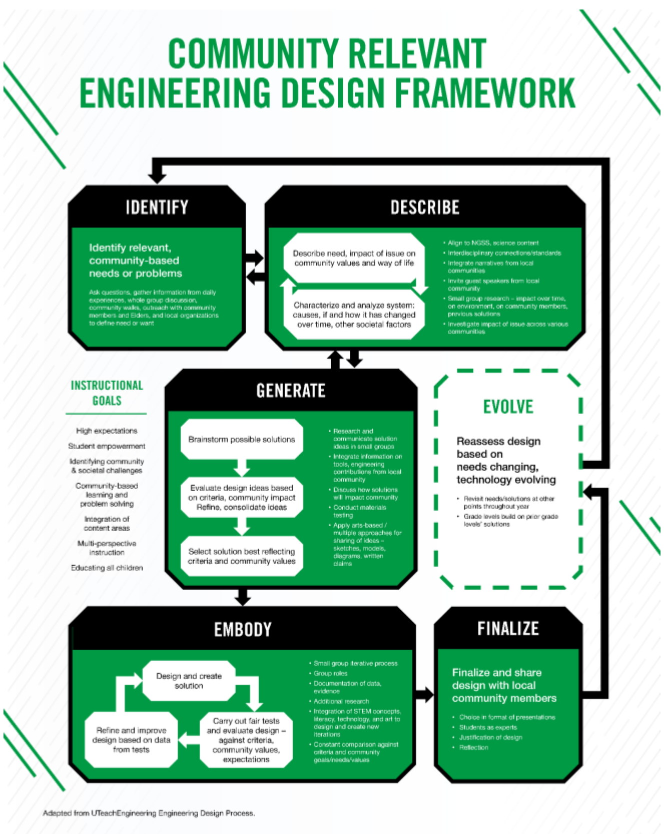

Figure 1. CRED Framework

CRETSE Conceptual Model

We propose the Community Relevant Engineering Teaching Self-Efficacy (CRETSE) Conceptual Model [Figure 2] [42]. The CRETSE Conceptual Model explains the integration of the Self-Efficacy (SE) Theories [31], NGSS [2] and our CRED framework [7] to describe the interaction between the components of our PD model and its impact on teacher CRETSE. The CRETSE Conceptual Model posits that PL situated within the sources of SE and targeted to teachers' existing levels of SE will impact both their engineering teaching SE as well as their community relevant teaching SE, moderated using the CRED framework, to support increased CRETSE. The gap between the level of SE that a teacher needs to implement CRED tasks in their classrooms as required by NGSS and the teacher's level of SE can arise from a lack of community relevant teaching SE, a lack of engineering teaching SE or a combination of both. By determining teachers' current levels of SE within these two distinct domains, our PL was then designed to meet those various entry points by providing targeted learning opportunities that could develop SE. This study assumes that with the PL, the teachers were able to develop CRETSE that they transferred to their classrooms to apply to their curriculum to teach students using the CRED framework as a guide.

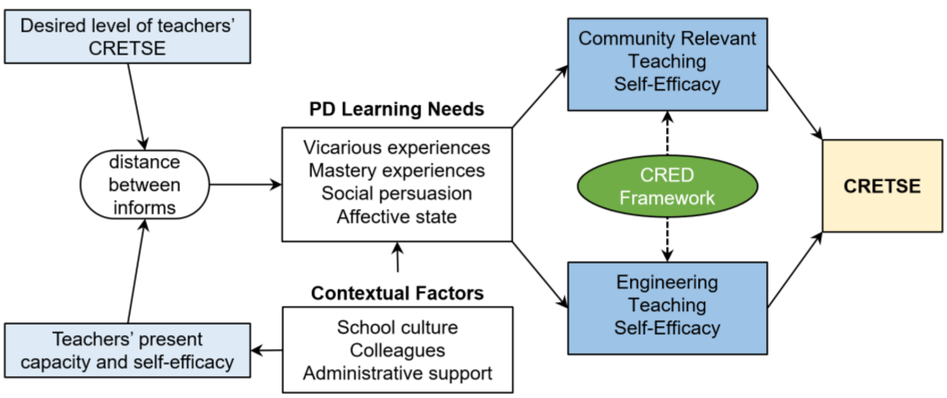

Figure 2. CRETSE Conceptual Model

5. Methods

Study Context

As part of an NSF-funded project, we conducted a two-year professional learning (PL) program for elementary and middle school teachers using the CRED framework [7] to develop their self-efficacy and instructional practice with implementing community relevant engineering design. The PL program included five PL days in the summer and three PL days during each academic year to help teachers develop and implement three CRED tasks in their classrooms.

Summer sessions focused on community relevant pedagogy, engineering design in NGSS and NGSS-aligned ND Science Standards, facilitating effective collaborative work, and the North Dakota Native American Essential Understandings. Teachers experienced a water filtration CRED task as learners and Tribal Elders worked with the teachers by sharing stories, community background, and insight into the local geographical and cultural context to support teachers' knowledge and integration of these connections within their lesson plans and designs. These sessions also helped teachers build collaborative networks for developing engineering curriculum tailored to their specific classroom and community contexts.

Academic year sessions were scheduled a few weeks before teachers implemented each of their three CRED tasks and were designed to give teachers time to collaborate, co-plan, and prepare engineering design tasks for their classrooms. Teachers received feedback and support from each other, and from professional learning specialists and the members of the research team.

Teachers developed community relevant engineering design tasks by first examining their required content standards and then considering issues that were relevant to their school communities to identify authentic areas that students could explore through engineering. The first engineering design task each year was the water filtration project from the summer PL that they adapted for their individual classrooms and curricular requirements. Teachers then developed two of their own CRED tasks. Some of the tasks developed by teachers included: exploring dam design parameters, designing a filtration system to improve indoor air quality, developing a severe weather app to be used by teen drivers, creating a model of a proposed recreation center for the town, exploring different forms of shelter used in the Northern Great Plains climate, designing a greenhouse to prolong the community's growing season, and testing wind turbine blade designs.

Participants

Participants in this study were four teachers who participated in our PL program (see Table 1). 15 teachers from four rural schools in the same region on or adjacent to Tribal Nations participated in the program. A first cohort of 8 teachers participated for two years, followed by a second cohort of 7 teachers who joined in the second year and participated together with the first cohort for one year. The four teachers in this study are from the first cohort of 8 teachers who participated for two full years and were selected to provide a range of experiences across grade levels, subjects and prior educational backgrounds.

Table 1. Participant Demographic Data

Participant*	**Grade Level Subject**	**Educational Background**	**Prior Years Teaching**	**STEM PD background**
Betty	8^{th} grade English	Middle & Secondary Level ELA	8	None reported
Michelle	5th/6^{th} grade STEM	Elementary & Middle Level Education	0	2 prior workshops in STEM education
Katie	5^{th} grade all subjects	Elementary Education & Library Science	15	3-4 prior workshops in STEM and place-based education
Emily	7^{th}/8^{th} grade Science	Animal Science, alternate pathway to Secondary Science Licensure	3	2 prior workshops in STEM education

**all names given are pseudonyms*

Betty: Betty is an 8th grade English Language Arts (ELA) teacher that had been teaching within rural and Tribal middle schools in the Midwestern region for eight years before starting to participate in our PL**.** Betty had no previous professional learning in STEM education but due to her interest in expanding her understanding and implementation of engineering education towards providing more project-based learning opportunities connected to ELA, and to enhance her community relevant approaches, she decided to participate in our PL. Some of Betty's colleagues who were Math and Science teachers in her school joined her to participate in our PL. This enabled Betty to develop her engineering tasks in collaboration with them, making scheduling and planning adjustments so that different aspects of the tasks could be completed across different subject areas, while still providing an overarching integrated approach. Betty approached the incorporation of engineering into her ELA class by connecting projects to the literature, literacy skills, and writing processes that students were engaged with. For example, when teaching the book "*Monster"* by Walter Dean Myers, which explores themes connected to race and teenage criminal activity, Betty asked students to delve into their own experiences with finding positive activities to do in their community that would help keep them out of trouble. The students then did an audit of their community assets and worked in small groups to design and build 3-D scale plans of recreational centers that would provide a safe place for teens while representing community interests and needs. By considering these connections to students' experiences and cultural contexts, Betty was able to incorporate stories, pedagogical approaches, and real-world learning that engaged her students and supported the growth of her own self-efficacy within community relevant engineering education. According to Betty, "seeing the impact on students and the opportunity for them to share about themselves led her to integrate these approaches more confidently and consistently". Betty described how allowing students to open up about their own lived experiences, how her incorporation of storytelling, and direct connections to features in the community provided framing and relevance for application of the ELA content.

Michelle*:* Michelle had been teaching in a rural K-12 school in the Midwest for four years as an afterschool teacher and administrative assistant without a teaching license. According to Michelle "I brought hardly any [background] with me. I was, at that time, an afterschool teacher only, and I didn't have any kind of license. I was working as a secretary when I started". Betty started to participate in Year 1 of the PL and passionately integrated the CRED tasks she developed in the PL into her afterschool program with such great success and student outcomes that the principal of her school offered her the opportunity to become the 5th and 6th grade STEM teacher at their school during the school day. With the career shift, Michelle enrolled in a graduate teacher education program to obtain her elementary teaching license and master's degree in education.

Michelle's STEM education training consists of two other workshops, and her science methods class as part of her teacher education program. Her professional learning in community relevant engineering education from the PL continued to impact on her teaching practice, pedagogy, and self-efficacy. She developed the STEM class curriculum for upper elementary students and an integral part of the 5th/6th grade teaching team as the sole STEM teacher in her school.

Katie*:* Katie is a fifth-grade teacher in a rural Midwestern middle school. She has been teaching for nineteen years and has extensive background in education, STEM, and place-based education. Katie had participated in several STEM professional learning offerings prior to our PL project, and was a leader in her educational community for curriculum development and innovative pedagogy and teaching practices. Unique about Katie's teaching experience and context is that she is one of two fifth grade teachers who run a program that partners with the U.S. Fish and Wildlife Service to offer a fully integrated and place-based educational experience. Situated on a local game preserve, the program is made available to fifth grade students through the public school system. Katie and her colleagues worked closely with other place-based education programs to redesign their grade-level curriculum to be interdisciplinary and directly connected to their local place, ecology, and community. Still aligned to all fifth-grade level standards, all student learning and lessons are connected to the outdoor environment and biocultural context. This unique and student-centered educational environment provides Katie with many opportunities to design and implement STEM activities that are authentic and relevant to the students and that reflect interests and phenomena within their surroundings.

Katie enrolled to participate in our PL to develop her self-efficacy in designing and implementing engineering tasks, and to be able to make connections to the local community. According to Katie "You know, I've done STEM activities, but it was the getting the culturally relevant piece that I felt like, and I have a lot of kids this year that are very involved in their culture, which is amazing. "Just figuring out the cultural piece of it. Like, I just need to figure out what specifically you know, what the kids' choices are going to be for their project. And then I'll figure out how can we tie it into the cultural piece?"

***Emily**:* Emily has a bachelor's and master's degree in animal science and worked in industry for 10 years as lab manager at an ethanol plant and a soil plant. While in industry, she enjoyed teaching the lab technicians who did not have solid chemistry backgrounds and basic lab skills. Due to a bad year for the ethanol industry, Emily moved to a new community, and was offered a job as a science teacher in the local middle school. Emily accepted the offer, began teaching and started the Alternative Pathway to Teacher Licensure through the State University. Emily had been teaching in the middle school for 5 years before enrolling to participate in our PL project.

Data Sources and Analysis

Data sources for this study include classroom observations of teachers' implementation of CRED lessons, interviews, and CRED-aligned lesson plans.

Teacher participants recorded an approximately 30-minute segment of each engineering lesson, focusing on their instructional moves, resulting in six videos of their engineering teaching over the course of the two-year project. Video recordings of teachers' CRED lesson implementation were analyzed using a modified version of the Classroom Observation Protocol for Engineering Design (COPED) [8] that tracks grouping of students, level of teacher support, and engineering design stages. We modified the tool to reflect the engineering design stages of the CRED framework and added codes for community and cultural connections included in the lesson, as suggested by the framework. (See Appendix)

We also conducted semi-structured individual interviews with the four participants after classroom implementation of each engineering design task (three interviews per year of the program). This study focused on interviews from the first year of the program. Interview questions explored participants' experiences during the PD, with implementation and sustainability of incorporating CRED-aligned tasks in their classrooms, and challenges faced with implementing CRED. Interviews were conducted via Zoom, lasted about 30 minutes each, and were transcribed using Zoom's transcription feature.

For each CRED lesson implemented in the classroom, teachers completed a lesson plan template during their academic year sessions and shared them with the research team prior to teaching their lessons. The lesson plan template was designed by the research team, modified from existing materials, to provide scaffolds for supporting teachers with CRED planning. It followed a backwards design structure [43] aligned to the NGSS [2] and included the specific CRED stages and instructional aims for teachers to outline and describe.

We analyzed both teacher interview transcripts and lesson plans using qualitative content analysis (QCA) [9] to develop codes and themes. The entire transcript for each teacher was treated as the primary unit of analysis. During the initial review, significant statements about CRED implementation, such as instructional actions, resource use, and student interactions, were identified as meaning units for coding and then related codes were grouped into broader, thematic categories. The process was iterative, moving back and forth between codes, categories, and raw data. To boost credibility, we used peer debriefing with colleagues familiar with CRED to review the coding scheme. We included thick descriptions of the categories, incorporating direct quotations from the transcripts in the findings. The final categories were analyzed and presented thematically. Each category is defined and illustrated with salient quotations from the teacher transcripts, providing a transparent link between the raw data and the interpreted strategies.

6. Findings

The process of qualitative content analysis of teachers' interview transcripts and lesson plans yielded eleven distinct codes which were then grouped into three overarching themes: CRED implementation, coordination, and approaches; connections to students' lives, communities, and culture; and teachers' experiences with CRED. Table 2 shows how these codes were categorized to create the themes and the definitions developed through the analysis process.

Table 2. Codes and themes identified from teacher interviews and lesson plans

Codes	Themes	Definitions
Interdisciplinary collaboration Teaching Strategies Curriculum Adjustments	CRED implementation, coordination, and approaches	Methods for planning and delivering CRED, including coordinating curriculum, teaching partners, and instructional strategies for engaging students
Cultural Relevance Place-based connections Local context integration Differentiation Student autonomy	Connections to students' lives, communities, and culture	Ways in which teachers make engineering tasks and content relevant to students' lives, contexts, communities, and individual learning needs
Teaching Confidence	Teachers' experiences with	Teachers' perspectives on

Progression Logistical Challenges Support (para, PD, admin)	CRED	their CRED implementation, growth, self-efficacy, experiences, and support over time

Our findings reveal the ways in which teachers implemented community relevant engineering design tasks in their classrooms, including their approaches connected to existing structures and curricular decisions, the ways in which they adapted their pedagogy to embed the CRED approach, and their perceptions and reflections connected to their own growth and experiences with adopting CRED principles. These themes highlight the key characteristics of the CRED framework and tasks that were most prevalent across teachers' implementation. They also indicate the ways in which teachers leveraged their resources across their educational community to enhance how students engaged with engineering tasks that were interdisciplinary and student-centered, relevant to students' lives, and authentic to the local culture and community. Findings will first discuss each teacher individually in relation to the themes and then will draw overarching conclusions across the teachers' experiences to answer the research questions.

Betty

As an English Language Arts teacher, Betty utilized her grade level team to plan for and implement an *interdisciplinary and collaborative approach to the CRED*. Working with the science and math teachers, Betty co-planned tasks with her teaching team in which different stages of the CRED were implemented in different classes. Specifically, the Identify and Describe stages, in which research and establishing context were key, were completed within the ELA class, with the Generate and Embody stages occurring in math and science classes. Often, the Finalize stage was connected to ELA curriculum and standards as well, with students practicing styles of writing and speaking in presenting their final designs. Lesson plans showed tools, such as anticipation guides and graphic organizers, included throughout the engineering lesson as a way for students to brainstorm and draw on their background knowledge. Betty also used a variety of collaborative teaching strategies in her classroom to support this work, including discussions, small group work, and connections to literature. Her curricular pacing guide and learning objectives helped to drive the timing and integration of the CRED tasks meaningfully into her existing instruction.

To *connect the engineering tasks to students' lives and the local community*, Betty used a variety of strategies. She both provided and elicited from students connections that were grounded in the local Indigenous culture, in the community features and infrastructure, and in students' lives and experiences. For example, when presenting a water filtration task, Betty invited students to share about the importance of water in their Indigenous culture and how they saw it presented across a variety of Disney movies that had Indigenous characters and contexts. She explained, "We ended up making a lot of connections to like Disney movies, oh, like *Frozen* and *Moana*. And how water is important within those. And then within each of those, there's an Indigenous population that's represented." She also brought in local water data and information about their water treatment plant, the largest in the region. Her lesson plans also show the inclusion of local maps, invited community members, and Elder interviews as a way to bring culture and community into the lessons. Brittany also incorporated the idea of community across many levels, from their classroom and school community to the broader town and region. Betty also embedded flexibility and student autonomy into the tasks, which allowed them to build on their strengths and interests for their designs. Students had many options for sharing their designs and responding, from creating videos, making presentations, or even using apps and cartoon graphics. Therefore, students' experiences and preferences were inherent throughout their progress through the CRED.

Betty described her *experiences with designing and implementing CRED* lessons and approaches as enhancing and expanding her existing ELA curriculum. While the collaborative and teaming approach to the tasks had benefits for providing an interdisciplinary and project-based experience for students, she did reflect that timing and coordination were challenging with other teachers. However, over time and with increased delivery of the lessons, Betty expressed that her self-efficacy, delivery, and alignment with teachers improved so that the CRED components and community connections became an inherent part of her teaching outside of the engineering tasks as well. "I think cultural relevance is now, it's just an active part of me as a teacher now, I don't even think about it." She also asserted that support of other teachers and paraeducators was extremely helpful in managing the logistics and students' needs throughout the CRED lessons.

Emily

While Emily was solely a science teacher, she also relied on coordination with her grade level team to *implement a more interdisciplinary CRED* learning experience for her students. Similarly to Betty, she noted that alignment with her teaching colleagues in other subject areas was most effective but required thoughtful and intentional coordination. Beyond simply implementing different stages of the CRED across classes, Emily also incorporated collaborative assessment during the Finalize stage; in other words, teachers from the various subject areas were able to assess different aspects of students' projects that were most relevant to that subject, which Emily felt resulted in a more robust and comprehensive evaluation. Her lesson plans also indicated that students were reporting on their full engineering design process to show how these interdisciplinary concepts and skills were infused throughout the stages. Emily also embedded engineering tasks into her existing science curriculum to help enhance conceptual understandings and meet learning goals within her science lessons. Tasks were completed in small groups, but Emily also intentionally embedded the use of technology to engage students and streamline approaches. Students used their phones frequently to research local data or used apps to brainstorm their designs.

While use of technology was a way to tap into resources, Emily also used it to provide *connections to students' lives and communities*. Accessing local data, designing apps for winter driving, and using online tools were all ways that Emily encouraged student autonomy, provided multiple modalities, tapped into students' interests and experiences, and connected students to their local community and conditions. Lesson plans show Emily's intent to have students share about their experiences with air and water quality in the school building before expanding out to data from the greater community or incorporating local cultural stories and traditions. Emily also provided choice for how students could approach and present their engineering tasks and frequently allowed students to follow their curiosity. During an air filtration task, for example, a student group wanted to take apart a fan to better understand how it worked. Not only did Emily encourage their exploration (as long as they could put it back together!), she also showed them how to use tools appropriately to do so. Emily engaged students with the environmental and cultural community as well by bringing in actual lake water for students to test and by sharing news and current events from the local community connected to their engineering tasks. “And so even though we had the kids filter the lake water, the actual community drinking water on the reservation is not tested often enough. And…often has a lot of contamination in it. So we talked about that and pulled that piece into the project.” She also encouraged students to think about issues of equity by comparing water and air quality data from their local context to other regions and groups. Finally, Emily provided important framing of engineering within a social context, a hallmark of Nature of Engineering, by requiring students to describe the stakeholders for whom they were creating their designs, how they would communicate and market their designs to this specific audience, and how their designs could be funded within the community.

Emily’s reflections on her *experiences with designing and implementing the CRED* reflect growing self-efficacy with not just the many components of the framework, but with monitoring her own learning and focusing on these different aspects intentionally as well. For example, she described using her experiences with a task to help her know what she wanted to focus on more for the next one - a more intentional connection to local culture, for example, or ensuring all stages of the CRED are equally addressed.

> Well, I think by the third one, like the first one, it was a deer in the headlights overwhelmed. Like, how is this gonna work? You know, and I dove really far into the model and the projects. And you know…later I'm like, I did kind of worry that maybe I didn't explain the entire engineering and the cultural design enough? So I focused in on that later. But, yeah, so overall I felt more comfortable with the process by the time we got to task three.

As her confidence grew, she described greater comfort with supporting all of her students in having a “growth mindset” with their engineering designing and learning, and she was more intentional about encouraging students, like her girls, who may by typically marginalized in a STEM setting, to see themselves as belonging in engineering. Increased student engagement was a motivator for her own increased self-efficacy. Emily described the value of support as well in implementing CRED tasks; in her case, connections to her school administrators and the school board created opportunities to elevate the students’ engineering projects and encourage her continued focus on incorporating them into her STEM classroom.

Katie

Being a 5th grade teacher, Katie taught all subjects and did not have the same interdisciplinary teaching team to collaborate with as Emily and Betty, however she also used the engineering tasks to enhance her science curriculum and aligned them to specific content and learning outcomes. Her *approach for implementing CRED lessons* also was similar in that she incorporated small group work and discussion. She also included team roles within the groups so that students had equal ownership, activity, and accountability with the tasks. Katie described the importance of having students experiment with materials and become familiar with their properties before designing solutions, so this was a step that she incorporated into the CRED stages. Further, she described the importance of students having experience and connection with the focus of the engineering tasks prior to designing solutions. While understanding the problem and context are infused in the Identify and Describe stages of the CRED, Katie expressed that engineering tasks were more effective and meaningful for students when they represented authentic experiences. As an example, she explained that her students had a more challenging time with the air quality task than the water filtration one because they had direct experiences with dirty water, but not with poor air quality.

Katie had designed her science curriculum to be connected to the local place and ecological context; therefore, she *connected to students' lives, communities, and culture* by embedding a place-based approach in which students were developing a sense of environmental stewardship through the engineering tasks. In this way, Katie drew students' attention to the long-term environmental and systemic impacts their engineering solutions could address. Katie also incorporated connections to students by inviting them to share their own personal stories connected to the local problem and how family careers were connected to environmental protection. Even for a student whose parent worked on the pipeline, she encouraged them to share how the systems were designed to mitigate leaks and the potential for oil to leach in the groundwater. Katie brought in additional community partners in connection with the engineering tasks as well, such as the local fire department.

> I had…two firefighters that came out and spoke with the kids before about the dangers of breathing in particulate matter and why you want [clean] air…it was really neat because the two gentlemen that came to speak with us grew up on the reservation and have family there. And so I mean, they're leading.

To ensure that the CRED tasks provided opportunities for student-directed learning, she also focused on students iterating their designs multiple times during the engineering design process and encouraged them to present all of their ideas and changes to their designs. Culminating presentations for the tasks as presented in Katie's lesson plans showed that students were sharing not just about their final designs but on their progress through each stage of the CRED as well.

For Katie, materials management remained a factor in her reflection about her *experiences with the CRED*. Materials that were tricky to manage, unfamiliar to students, or hard to store impacted her sense of success and self-efficacy with implementing the tasks. She discussed, "when it's something they're not comfortable with, and something they're not familiar with…I just have to figure out how to make it more, you know, applicable to their daily lives." However, she discussed that as she reflected on her teaching and finalized her lesson plans and materials based on her experiences for future implementation, her confidence and comfort increased to continue CRED lessons in the future. "I just felt a lot more comfortable. You know, I've done STEM activities…but it was getting the culturally relevant piece that I felt like, and I have a lot of kids this year that are very involved in their culture, it's amazing."

Michelle

Like Katie, Michelle was also an elementary teacher but, in her case, only taught the STEM curriculum. To *implement CRED lessons* throughout her curriculum, Michelle made meaningful connections to engineering within all of her science units. She even described bringing in engineering tasks to support students' understanding within life sciences, such as within a pollinators unit and to explore insect and plant structures. Similarly to other participants, Michelle incorporated small group work within the tasks, with an intentional focus on the role of mentorship and strategic partnerships to foster successful group dynamics. She describes thinking carefully about how students with different expertise and strengths could support each other in collaborative groups and how these decisions helped to increase the groups' productivity and outcomes. Michelle also integrated writing into her engineering tasks to help students explain and consolidate their thinking and utilized online resources to support her curriculum development and to enhance the information and context she provided students for the CRED tasks. She accessed local news and recorded interviews and stories from local Tribal Elders to infuse into her Identify and Describe stages of the CRED, thereby providing interdisciplinary content even with a STEM-focused class.

Such available online resources also provided meaningful *connections to students' lives, communities, and culture.* Michelle used informational videos and Elder interviews grounded in community experiences to anchor students to the engineering problem context. These resources highlighted important ties to students' cultures, their lived experiences, and regional characteristics, such as climate and histories. For example, integrating social studies and science, Michelle shared a video with students focused on the types of traditional Native American shelters created to withstand the windy and harsh climate of the plains. After learning about the shelters through the video, students used their understanding about the design structures to create their own model shelters and tested them against simulated weather conditions. She explained, "it was way easier this time, because I was able to tie it in with a video and, you know, it's something that they all know about. A lot of them have Indigenous descent. So, you know, they're familiar with the different types of housing and stuff." Michelle also invited community partners to speak to her class, drawing connections between engineering concepts and the design process to careers and local occupations. While Michelle shared a concern about herself teaching students about their culture, she integrated the voices of community members to provide the teaching, stories, and information themselves, which allowed for authentic cultural learning to occur through the CRED tasks. Her lesson plans provide evidence of this approach, with cultural stories, community members, and connections to careers woven throughout the CRED stages and across the tasks. To further foster students' ownership, creativity, and autonomy within the tasks, Michelle consistently provided students with choice of materials and the opportunity to bring in their own additions from home.

Michelle felt that her incorporation of student-directed learning contributed significantly to their engagement, which thus impacted her self-efficacy and comfort with her *experiences implementing CRED tasks*. In fact, Michelle's confidence and enjoyment of implementing the tasks increased so greatly that her school administration increased her STEM leadership and teaching capacity over the two-year project. This sense of support from her administration, as well as on-going collaboration through the project PL itself, were key factors in her continued efforts to integrate and expand her engineering teaching, and she described her self-efficacy increasing with the on-going experience and practice with each new task.

> And teaching my first STEM class, this last year, I was able to employ a lot of those things that I had learned about teaching engineering to the kids. And so it just made it a whole lot easier for me with you know, because you, you not only learn about the hands on stuff, but you see it like you see the kids figuring things out. And it's like, the coolest thing ever. So I don't know if you can really measure that.

As her confidence increased, so did her ability to navigate when things did not necessarily go as planned within a task; thus rather than such experiences discouraging her or decreasing her self-efficacy, she felt they were opportunities to learn, adapt, and make changes for next time.

These qualitative insights are complemented by quantitative data from the modified COPED demonstrating how teachers' practice evolved over time. Figure 3 shows how these four teachers shifted their instructional practice towards greater student control. Their teaching moved from mainly teacher-driven (TDR) and teacher-directed (TDIR) instruction to increasingly student-directed (SDIR) and student-driven (SDR) approaches. In the first engineering design tasks during year one, learning was largely teacher-driven and teacher -directed, but subsequent tasks showed a shift in focus from teacher to students. By year two, teachers were facilitating lessons that were primarily student-directed and student-driven.

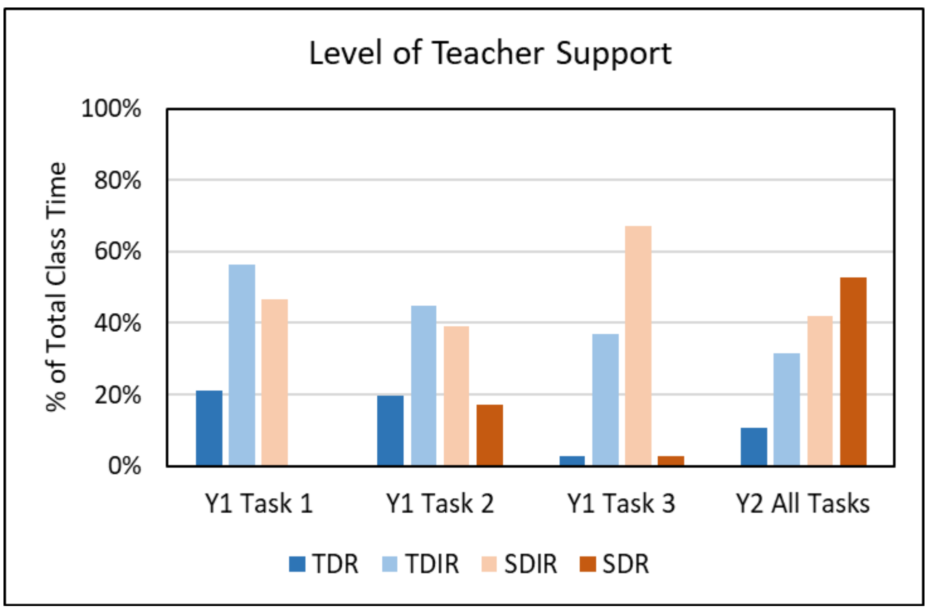

Figure 3. Frequency of observed teacher support level type during CRED task classroom sessions across two years of professional learning for study participants. Teacher support level defined by COPED categories: TDR = teacher-driven, TDIR = teacher-directed, SDIR = student-directed, SDR = student-driven.

7. Discussion

This study aimed to answer the following two research questions through analysis of four teachers' planning, implementation, and reflection on their experiences teaching CRED-aligned lessons:

- How do teachers design and implement community relevant engineering design in their classrooms in response to on-going PL?
- What key instructional features and strategies of a community relevant approach to engineering education are most emphasized or adapted in teachers' lesson design and implementation?

While these four teachers were in unique situations and used the CRED materials and approaches in ways that were most aligned to their individual contexts, key commonalities emerged across their experiences with implementing the CRED. For all teachers, the CRED lessons afforded them opportunities for integration and curriculum enhancement. Rather than isolated activities, the teachers used the tasks within existing content and curriculum across all subject areas and made meaningful connections to grade level standards and learning objectives. This interdisciplinary approach allowed teachers to embed not just subject-specific concepts (such as science and social studies) within the tasks but to also incorporate essential practices and skills, such as writing, speaking, and technology integration. Whether in collaboration with grade level teaching team partners or within a self-contained classroom, these teachers approached their CRED lessons as opportunities to deepen students' understandings and assess their knowledge and skills more comprehensively. In doing so, teachers were naturally aligning to the three-dimensional approach emphasized by the NGSS [2] in which disciplinary knowledge, practices, and cross-cutting concepts are intertwined.

To make these meaningful connections between the CRED tasks and grade level curriculum, teachers also made intentional decisions about when, how, and where in their year-long planning to implement the tasks. Using their pacing guides and collaboration and coordination with teammates, they outlined the tasks over the course of their year to meet the outcomes of their existing curricula. In other words, the tasks were used to reframe, complement, or culminate an existing unit rather than serve as stand-alone tasks, highlighting the potential of the CRED framework to support pedagogical and instructional shifts in teachers' practice rather than provide a decontextualized or "one-size-fits-all" template.

While implementation of CRED allowed teachers to make changes to their overall curriculum implementation and lesson design, they also showed shifts in their instructional practices within the classroom. For example, all teachers discussed the use of small group or partner work with students during the tasks. While teachers expressed different levels of experience with collaborative work, they all described shifts and greater intentionality with how they implemented this approach through the CRED tasks. Assigning roles and strategic partnerships to support more equitable participation were ways in which the teachers described making the groupings more effective and productive for student learning and participation. As teachers continued to provide such scaffolds over the course of the tasks, this effectiveness was corroborated by the COPED analysis of classroom videos as well, with teachers de-centering themselves more across the stages of the CRED.

Teachers made meaningful connections to students and their culture and community in a variety of ways, as outlined in the CRED framework. All teachers provided choice and flexibility for how students engaged with the tasks and presented their results: from offering different modalities, tools, and hands-on materials to providing open-ended approaches for students to design solutions, teachers allowed students to build from their own creativity, strengths, and learning preferences. In doing so, students were able to connect with the tasks more personally and to pursue lines of investigation and problem-solving that were most relevant to them.

In addition, teachers created direct connections to students' lives by incorporating engineering problems that were relevant to students' experiences within their communities. Bringing in community partners, visiting features in the community, drawing on students' experiences (recreation at the local lake, winter driving, or family careers, for example), and sharing local news and data were ways that teachers helped students understand the authentic context of the problems within their locality. Teachers also allowed time for students to conduct their own research and understand the problem within the local place-based, ecological settings as well. This intentional framing enriched the Identify and Describe stages of the CRED and the opportunity for students to engage in problem-scoping, often overlooked in engineering instruction in K-12 classrooms.

Cultural connections, histories, and understandings were another feature of teachers' CRED lessons that were emphasized in their classrooms. Teachers utilized resources available for classroom use, such as recorded Elder interviews and stories from students' cultural communities, to contextualize the engineering problems within cultural values and experiences as well. They also tapped into students' own cultural teachings and beliefs. In this way, problems were situated within impact and importance to the specific cultural community (the sacredness of water, for example), not just with the physical location. In Michelle's example with teaching about Indigenous shelters and structure designs from the local region, students were able to situate their solutions within cultural knowledge as well. Across the four cases and the varied tasks, culture was incorporated in unique ways - as part of the framing of the problem, to elicit student ideas, and to suggest possible design solutions. In all of these approaches, however, students had the potential to see the socio-cultural context of engineering, to see engineering feats and designs within Indigenous science and ecological knowledge, and to potentially expand their sense of "who does engineering".

Despite different levels of training and background experience in STEM teaching and curriculum, all teacher participants reported growth in their engineering teaching self-efficacy and shifts in practice, which were evident in the classroom observations and lesson plans. While support from colleagues, administration, and the PL itself over time were instrumental in supporting these changes, all four teachers described learning from their experiences and reflections, gaining more comfort with letting students take the lead, and feeling more enthusiastic about planning and teaching future engineering lessons due to on-going practice and experience.

Findings from this study of four teachers implementing CRED-aligned lessons provide important understandings about the ways in which they plan and incorporate them into their classrooms, as well as principles and approaches that are most prevalent as they adapt the CRED framework. Given the different grade levels, subjects, and contexts of these four teachings, identifying key features of CRED teaching and learning across their experiences can help to identify aspects of CRED that are generalizable for more teachers and broader dissemination. However, these findings also extend prior literature about the ways in which engineering PL can support teachers' self-efficacy with teaching engineering and the connections to NOE that can be integrated as part of training. In each case, as these teachers used the CRED framework to guide their planning and incorporated authentic connections to students' lives, experiences, and communities, they engaged students in problem-identification and problem-scoping with relevant and real-world issues. Thus, this work confirms prior research that asserts the importance of on-going PL on teachers' self-efficacy with teaching and implementing community-connected engineering but also shows that explicit scaffolds and frameworks like the CRED framework can expand the ways in which teachers engage students in the full EDP, including the problem-identification and scoping phases. Further, use of the CRED allowed teachers to address aspects of NOE that are rarely made explicit in pre-college engineering education. While not specifically identified on the CRED framework, situating engineering within community and cultural relevance allowed for greater emphasis on creativity, subjectivity, the socio-cultural context, failure and iteration, and on the engineering design process itself - all key tenets of NOE. This alignment suggests that such direct support and scaffolding of NOE principles can be effectively integrated into PL to increase teachers' self-efficacy and their readiness to develop and curate inter-disciplinary curriculum within an engineering context.

Recent policy and reform documents call for students to learn about the impacts of engineering on society, its role in addressing local and global challenges, and for educators to provide students with opportunities to engage in engineering tasks that are connected to meaningful real world problems, especially those that are relevant to their lived experiences [1, 2]. Our findings reveal that meaningful and on-going PL that engages teachers in experiencing and using the CRED framework can influence not just their self-efficacy to teach community relevant engineering but their planning and practice as well. As emphasized in the literature and as described by these four teachers, by embedding community and student-centered approaches throughout each stage of the EDP, all students were more engaged, invested, and participatory in designing solutions that had relevance to their lives and lived experiences.

8. Conclusion and Next Steps

Our study provided compelling findings about the ways in which these four teachers incorporated CRED principles into their engineering planning and instruction. It also showed the structures and approaches they leveraged to make their CRED implementation manageable and effective within their specific educational contexts. As a result of the PL model and training with the CRED framework, teachers incorporated some key CRED characteristics, including interdisciplinary instruction, relevant and community-based problems, small group work, connection with community members, multiple modalities and student choice, and evidenced-based iteration. They also focused on the full EDP, with lessons designed to engage students in each stage explicitly and intentionally.

Next steps with this research will be to analyze data and expand the findings across a larger cohort and multiple years of the project to determine if these common CRED principles and instructional approaches remain true over time and participants. To do so, we will continue to further our analysis of interview transcripts, lesson plans, and classroom video to reveal other possible patterns with teachers' CRED implementation. Further, our findings provide clear connections to developing NOE tenets within the pre-college engineering classroom. Our research will continue to explore how teachers' and students' understanding of and engagement in NOE can be supported by use of the CRED materials and approach. Lastly, as we gain a clearer understanding of the characteristics and approaches that were most common among teachers as they incorporated CRED into the year-long classroom curriculum and instruction, we will return to the CRED framework to reflect on elements that may be less prevalent in teachers' practice and how those may be further bolstered in future PL offerings and in revisions or enhancements to the CRED framework itself. This body of work will provide important implications for future community relevant engineering PL and practice.

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Appendix

Video Observation – Modified COPED

Engineering Design Framework

Stage	Code	Descriptors
Identify	ID	• Gather information from community • Whole group problem identification/definition
Describe	DESC	• Describe impact on local and cultural community • Describe problem over time/context • Gather information from community members • Research
Generate	GEN	• Brainstorm solutions • Identify criteria • Evaluate ideas • Revise ideas • Finalize/select solution
Embody	EMB	• Design/create solution model • Test • Refine/improve design
Finalize	FIN	• Finalize design • Share design
(Evolve)	EV	(NA)

Grouping

Whole Group	WG	The entire class is engaged in the same discussion, working together on the same task. Examples are teacher-led, open-ended questions/discussions involving back and forth with multiple students while others listen, teacher-led demonstrations or lectures, and students presenting their work to the entire class.
Small Group	SG	three or more students working together and engaging in discussions/tasks related to content, can include cooperative learning groups with individual roles, group accountability, and group processing. Examples are students working in a group of 3-5 to build or test a prototype.
Partners	P	Two students working together and engaging in discussions/tasks related to content.
Individual	I	Student is working on a task alone (e.g. individual thinking/task/problem solving). Examples are students working individually to generate a list of ideas (brainstorming) of how to solve a problem.

Teacher/student focus

Teacher-driven	TDR	Teacher provides explicit challenges and constraints/requirements, models brainstorming, provides information/plan/solution ideas, tests ideas, teacher communicates solutions
Teacher-directed	TDIR	Teacher leads students in developing problem, guides students in brainstorming ideas, provides research resources, provides steps and directions for how students will design and test their ideas, teacher leads communication of solutions with some student input
Student-directed	SDIR	Students develop problem/challenge with some teacher input, students brainstorm ideas with some teacher guidance, students find research resources with some teacher guidance, students develop, create, test their design ideas with some teacher feedback and guidance, students select from teacher provided options how to share solutions
Student-driven	SDR	Students develop problem/challenge with minimal or no teacher input, students brainstorm ideas with minimal teacher guidance, students find research resources with minimal teacher guidance, students develop, create, test their design ideas with minimal teacher feedback and guidance, students decide how to communicate their solutions

Culturally Relevant Components

Connection to community/cultural context/history	CC	Elder interviews/visits, reference to local places/features, historical narratives (pedagogical approaches)
Connection to students' culture/lives	SC	Home-school-family connections, incorporating student interests and experiences
Inclusion of cultural elements	CE	Including stories, games, language, songs, books, bulletin board displays from local cultural communities. (using direct cultural resources)
Inclusion of arts/creativity	AC	Open-ended design, connection to Native art, providing art tools for creating design solutions

Observation Tool for Videos

Time	Grouping	Teacher/student focus	ED Components	Cultural Components	Description/Evidence/Examples of CRED Elements
0 - 2	WG SG P I	TDR TDIR SDIR SDR	ID DESC GEN EMB FIN	CC SC CE AC	
2 - 4	WG SG P I	TDR TDIR SDIR SDR	ID DESC GEN EMB FIN	CC SC CE AC	
4-6	WG SG P I	TDR TDIR SDIR SDR	ID DESC GEN EMB FIN	CC SC CE AC	
6-8	WG SG P I	TDR TDIR SDIR SDR	ID DESC GEN EMB FIN	CC SC CE AC	