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Exploring Teachers' Lived Experiences with Culturally Relevant Engineering Design: An Instrumental Multiple Case Study

Dr. Julie Robinson, University of North Dakota

Dr. Julie Robinson is an Assistant Professor at the University of North Dakota and the Director of UND's Center for Engineering Education Research. Her research explores strategies for broadening access and participation in STEM, focusing on culturally relevant pedagogy in science and engineering. She also investigates strategies for increasing representation in STEM through teacher professional learning opportunities and by exploring the impact of group gender composition on girls' motivation and engagement. Dr. Robinson is a PI and Co-PI on several NSF sponsored grant projects which focus on teacher professional learning and self-efficacy with implementing culturally relevant engineering education, connecting to place and community, and centering culture and Indigeneity within STEM education. Dr. Robinson has over twenty years of K – 12 teaching experience, including seven years as a teacher leader of professional development in the Next Generation Science Standards, the Common Core State Standards in Mathematics, and in elementary science and engineering pedagogy.

Dr. Frank M. Bowman, University of North Dakota

Dr. Frank Bowman is Thomas C. Owens Endowed Chair, Professor and Chair in the Department of Chemical Engineering at the University of North Dakota. He holds a Ph.D. from the California Institute of Technology and a B.S from Brigham Young University.

Dr. Bethany Jean Klemetsrud P.E., University of North Dakota

Beth Klemetsrud is an assistant professor at the University of North Dakota where she studies equity and culturally relevant pedagogy in engineering education, waste to energy conversion, and life cycle assessment. Beth is from the White Earth Nation and is grateful to be able to work on my homelands and to be so close to my family and community. She graduated with her Bachelor of Science in Chemical Engineering at the University of Minnesota Duluth. She obtained her doctorate from Michigan Tech under the supervision of Dr. David Shonnard where she focused on renewable energy production and life cycle assessment of biobased energy production from hybrid poplar.

Mr. Adesola Samson Adetunji, University of North Dakota

Adetunji Adesola is a Graduate Research Assistant in the Department of Chemical Engineering at the University of North Dakota and a member of the Center for Engineering Education Research (CEER). His research focuses on culturally relevant engineering design, engineering identity development, and strategies for increasing the representation of underrepresented groups in STEM education. He employs mixed methods approaches to promote equity and inclusion in K-12 STEM education, advance engineering workforce development, and foster inclusive practices in engineering education.

Adesikeola Olateru-Olagbegi, University of North Dakota

Exploring Teachers' Lived Experiences with Culturally Relevant Engineering Design: An Instrumental Multiple Case Study (Work in Progress)

Purpose

The Next Generation Science Standards (NGSS) [1] emphasize connecting science and engineering to local contexts so that standards are relevant for all students. Yet many teachers lack sufficient training or self-efficacy (SE) with implementing engineering education, leading to superficial or decontextualized engineering teaching approaches, less student-centered pedagogy, and reduced student outcomes [2]. To address this gap in engineering education, we developed a Culturally Relevant Engineering Design (CRED) framework and two-year CRED PD program [3].

This work-in-progress instrumental multiple case study [4] explores the lived experiences of three teachers who received our CRED PD, reported moderate to high levels of SE with implementing CRED, and are regularly integrating CRED lessons in their classrooms. Through this approach, we aim to gain a deeper understanding of these participants' experiences, first individually and then as a group (unit of analysis), to provide insight into challenges still faced by teachers with implementing CRED lessons despite growing SE, guided by the following research questions:

- How do teachers with moderate or high levels of culturally relevant engineering teaching self-efficacy describe their learning trajectories, instructional shifts, and impacts from PD?
- What do teachers with moderate or high levels of culturally relevant engineering teaching self-efficacy perceive as challenges with implementing CRED-aligned tasks?

Theoretical and Conceptual Frameworks

To effectively integrate culture into K-12 engineering, teachers must be effectively trained and empowered to employ a culturally relevant approach [5] to engineering that centers classroom instruction in multi-ethnic cultural frames of reference [6] Effective culturally relevant engineering teaching can increase student engagement, outcomes, and representation within STEM, particularly for students who have not historically viewed science and engineering as relevant to their lives or as an area in which they can engage [5].

Our study is framed by Bandura's Social Learning Theory [7], which explains how humans learn new behaviors through observation, imitation, and modeling. Inherent in this theory is the construct of self-efficacy (SE) [7] which arises from four sources: vicarious experiences, mastery experiences, physical or affective states, and social or verbal persuasion. Palmer [8] extended Bandura's SE theory by emphasizing the role of contextual factors that also influence teachers' SE such as school culture, colleagues, and administrative support and the need to examine SE within specific domains rather than relying on general SE measures. SE is crucial for understanding teachers' implementation of and experience with CRED as many remain under-confident in engineering content, pedagogy, and standards [2,9,10]. This phenomenon emerges from a lack of background knowledge, limited support for PD and curriculum development, few resources and materials, and insufficient training in teaching to a new set of standards [2,11-13]. Research similarly shows that a lack of training and background knowledge affects teachers' culturally responsive teaching SE as well [14]. Teacher SE in any content area is a strong predictor of student motivation and learning outcomes, as teachers' perceptions of their own knowledge directly affect their instructional effectiveness [2,9,10,14,15]. Thus, effective PD to impact teachers' engineering practice must be rooted in sources of SE and culturally relevant and engineering teaching SE.

Our research team developed a Culturally Relevant Engineering Design (CRED) framework (See Appendix) and PD model aligned to SE and culturally relevant and responsive pedagogical approaches [3]. The CRED framework provides a guide for connecting engineering lessons to local community contexts and utilizing best practices in engineering instruction and culturally relevant pedagogy for each stage of the design process (Identify, Describe, Generate, Embody, Finalize, Evolve). The two-year PD model included mentorship on engineering in NGSS and implementing the CRED framework, while also providing time for teachers to experience CRED-aligned tasks as learners, design their own CRED tasks, and partner with Elders from local Tribal Nations for community connections. 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. The PD model included five PD days in the summer and three PD days during each academic year to help teachers develop and implement three CRED tasks in their classrooms.

Melding our PD model and theoretical foundations together, we propose the Culturally Relevant Engineering Teaching Self-Efficacy (CRETSE) Conceptual Model (see Figure 1). CRETSE integrates SE Theories [7,8,14], NGSS [1], and our CRED Framework to explain the interaction between the components of our PD model and its impact on teachers' CRETSE. The CRETSE Conceptual Model posits that PD 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 culturally 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 culturally 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 PD was then designed to meet those various entry points by providing targeted learning opportunities that could develop SE. Examples of learning opportunities aligned to sources of SE include modules on culturally relevant pedagogy, peer feedback, consultation with learning specialists and engineers, collaborative planning, and model lessons to allow teachers to develop the following sub-dimensions of CRETSE: culturally relevant content and pedagogy, confidence and efficacy with teaching and facilitating student learning in CRED, and facilitating students' design process and products in a culturally relevant manner.

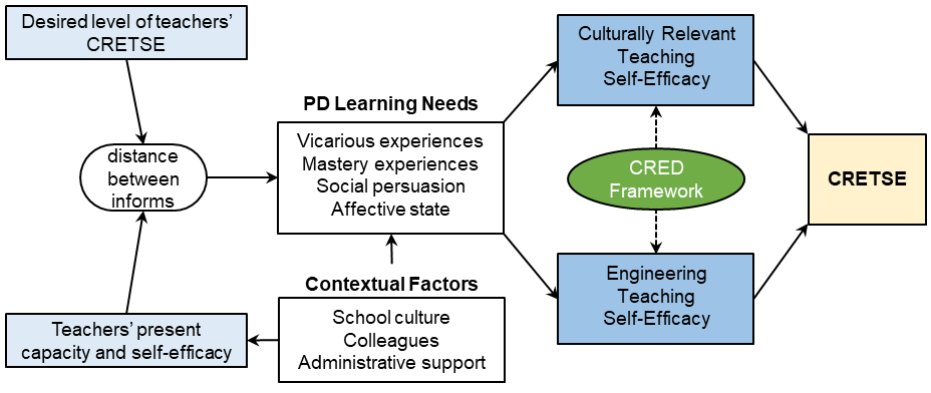

Figure 1. CRETSE Conceptual Model

Methods

Participants

Participants in this study include three teachers from our full study cohort who exhibited moderate to high levels of CRETSE at the culmination of our full two-year PD program (see Table 1). Teachers in the full program came from four different regional schools on or adjacent to Tribal Nations. Each school represented had more than one teacher participating in the study, so participants had both a cohort from their school as well as a cohort within the larger study. The three teachers in this study are from two participating schools.

Table 1. Participant Demographic Data

Participant*	Grade Level Subject	Educational Background	Years Teaching	STEM PD background
Betty	8th grade English	Middle and Secondary Level ELA	12	None reported
Michelle	5th/6th grade STEM	Elementary and Middle Level Education	4	2 prior workshops in STEM education
Katie	5th grade all subjects	Elementary Education & Library Science	19	3 - 4 prior workshops in STEM and place-based education

**all names given are pseudonyms*

Data Sources and Analysis

Teacher participants recorded an approximately 30-minute segment of each engineering lesson annually, 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' culturally relevant engineering lesson implementation are currently being analyzed using a modified version of the Classroom Observation Protocol for Engineering Design (COPED) [16]. 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 each of the three participants both during and six months after the PD program (three interviews per year of the program and one final interview, totaling seven interviews). 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 analysis of interview data, we are using a codebook developed as part of a six-step thematic analysis process [17]. Three authors independently code the interview data and then meet for collaborative sense-making sessions to discuss their independent coding and compare results to establish consensus on the final codes and themes that have emerged from the data. We will continue to refine our codes and themes as we review the data, considering our research questions, so that we accurately interpret the data through our CRETSE Conceptual Model.

Preliminary Findings

Our preliminary analysis has revealed four themes aligned to how teachers describe their learning trajectories and SE with implementing CRED tasks as a result of the PD.

Theme #1 Community and Cultural Connections

Classroom video data illustrated that teacher participants regularly connected the engineering tasks and related content to students and their local community context. These connections were particularly evident during the Identify and Describe stages of the CRED framework and lesson sequence as teachers launched their engineering lessons within students' lived experiences. Michelle, for example, invited her students to explore different types of shelters used by Native American Tribes across the region and to learn about their structures and functions before students then designed their own shelters that would withstand winter winds and snow.

As teachers reflected on their SE with incorporating community and cultural connections, they indicated that *direct instruction in culturally relevant pedagogy* and *opportunities to research and plan* for these connections throughout the PD were transformative to their teaching. As Betty described integrating cultural connections across content areas, she explained, "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." Katie described her enthusiasm with connecting to her Indigenous students' lived experiences. "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." In these instances, each teacher showed the conscious and explicit ways they were growing their culturally relevant practice as a result of the PD structures.

Theme #2 Student Impact and Outcomes

Analysis of video data also showed teachers facilitating *increased student direction and autonomy* of the tasks within each of the classrooms over the two-year period; however, this characteristic is more variable across the three case study participants. Michelle and Katie increasingly enabled student-directed learning early on in the Identify and Describe stages of their lessons, while Betty remained more likely to shift to a more student-centered approach later, during the Generate and Create stages. In each teacher's classroom, however, students were observed to *work collaboratively in groups*, *direct aspects of the task and their designs* with minimal teacher facilitation, and *show their voice, creativity, and interest* in how they approached their designs.

When discussing students' responses to CRED-aligned tasks, all three teachers remarked on the impacts they observed in their students over time and how this affected their own SE with implementing CRED. They described a dramatic *increase in student engagement* during the tasks, noting that students who were most likely to struggle in other aspects of their school day thrived in these learning experiences. When Betty shared about the task her students completed to design a town recreation center, she described how her students were so involved in understanding the context that they initiated an exploration of resources available in their community. Each teacher identified individual students who they saw *taking on leadership roles* within these tasks for the first time. Michelle discussed that, despite having what she described as a challenging class, many of the *student behaviors* displayed during other times of day were absent during the CRED tasks. In each of these cases, teachers described how the student outcomes and engagement made them more eager and comfortable with planning for more CRED tasks in the future. Katie emphasized, "Students learn better when it's hands-on and they are coming up with ideas on their own."

Theme #3 CRED Professional Development Model/Strategies

A third theme emerged from the interview data as our case study teachers described specific PD components that were most influential in impacting practice. Most significantly, teachers described the benefit of *chunking and direct application of content* on their learning trajectories. Michelle explained how valuable it was that new ideas were introduced in small doses and then "giving us time to work on it right then and there, what was being taught". *Collaboration and a cohort model* also emerged as essential aspects of the PD, with Betty describing how she was going to continue to recruit her colleagues into collaborating with her on designing and implementing CRED-aligned tasks due to the PD and Michelle explaining that "networking became the biggest part of what they were able to do together". *Access to content experts and learning specialists* throughout the PD, e*xperiencing the CRED approach and framework as a learner*, and the opportunity for *practice and repetition* were highlighted by all three teachers as crucial characteristics of the PD that increased their confidence and enthusiasm for implementing CRED tasks.

Theme #4 Teaching Practice and Pedagogy (challenges)

A fourth theme centered on teaching practice captured many ideas related to challenges with implementing CRED lessons. A *sense of isolation and lack of a cohort* once the PD was over was the main barrier teachers described. Michelle discussed that teachers worked in silos in her school and did not collaborate with each other. Katie also lamented the loss of a cohort, saying, "And once we were done with the training…we've had people that did the project…that have gone to different schools, or have left teaching, or we're in different grade levels now, so we're not working as closely with people as we were. So now we're kind of back to where I feel like we're an island."

Time constraints, pacing, and scheduling logistics were also common challenges voiced by our three teachers. Katie described how a lack of teachers and substitutes had reduced their planning time, limiting her ability to design and plan CRED tasks. Betty echoed this, saying that implementing the CRED tasks took substantial time and made adhering to her district-mandated curriculum pacing guide a challenging balance. Finding ways to weave tasks into the existing curriculum, while optimum, was also challenging for teachers, especially when they had designed tasks that no longer fit into their current curriculum map (and without time to design new ones).

Michelle identified a final barrier to her CRED implementation, which was not voiced by the other teachers but was noteworthy in terms of its connection to the aims of the CRED Framework. She explained that a *lack of community resources and partnerships* impeded facilitating CRED tasks well. She explained, "Especially if you're in a rural area, you're not going to have a lot of community options…we had a great extension office, and the lady retired, and now we don't have anybody, so you're missing a huge piece just from her retiring."

Next Steps

Emerging findings shed light on how teachers' practice and SE transformed through our PD model, but also ongoing challenges with the sustainability of implementing CRED tasks despite teachers' readiness to do so. The research team is continuing analysis of classroom videos and interviews of the three case study teachers. Next steps include the completion of analysis of each of the data sources to generate findings about our participants' experiences. We will then interpret and triangulate findings across data sources for each participant to create rich individual case study descriptions as well as to determine commonalities across the three cases to better understand how teachers develop culturally relevant teaching SE and the challenges they continue to face with

implementing CRED tasks despite their moderate to high levels of CRETSE, as suggested by the instrumental case study approach [4]. Our analysis will link findings back to the literature and update the CRETSE model with insights on contextual factors affecting SE. In addition, we hope that our analysis will suggest impactful practices for mitigating such challenges, such as providing online cohorts for collaboration across contexts and outside of the school day and developing online asynchronous PD modules that teachers can access more flexibly.

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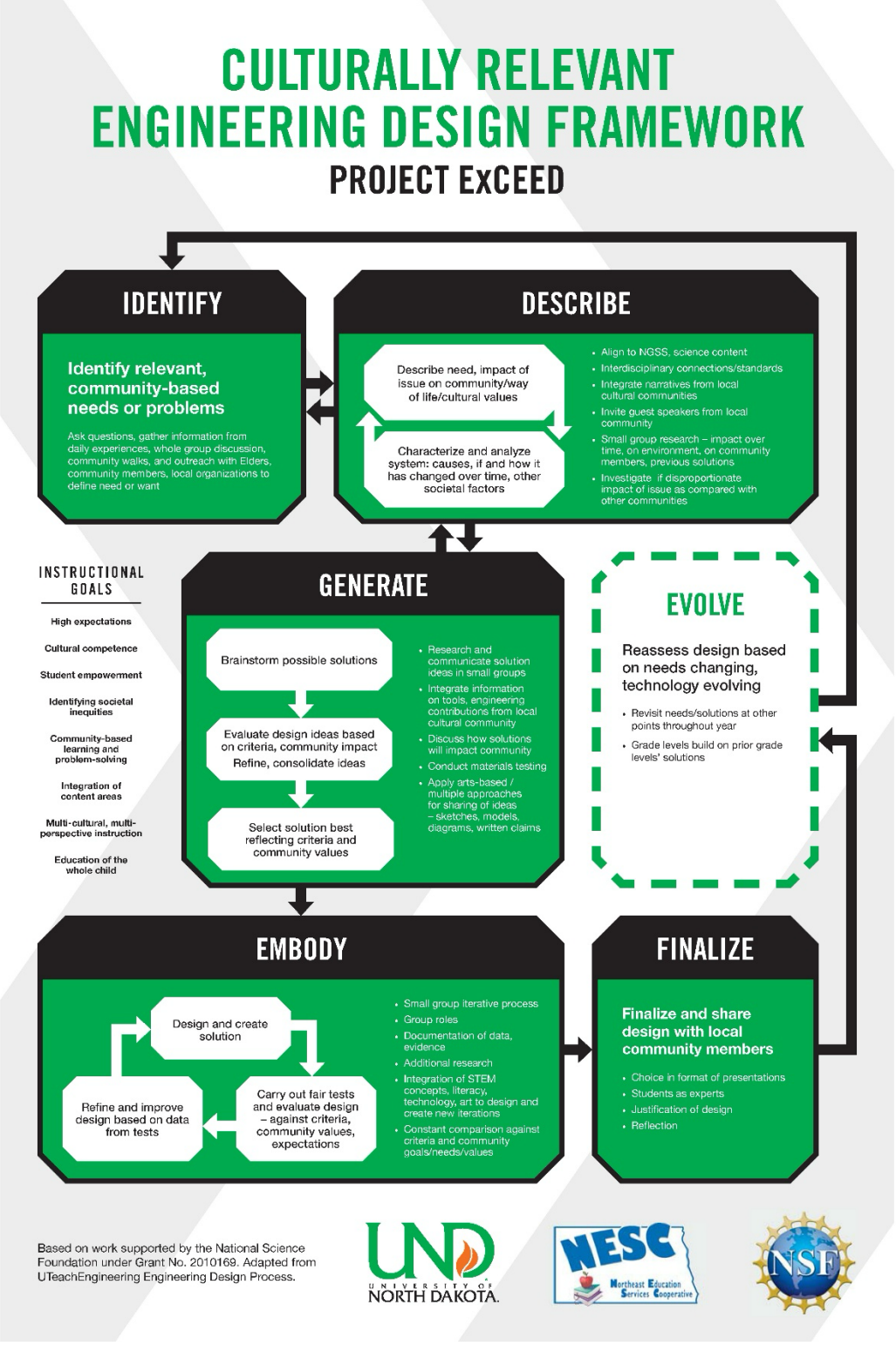
Appendix

Culturally Relevant Engineering Design (CRED) Framework



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PRE-OBSERVATION (to be completed by the teacher)

1. Background information:

Teacher name:	Date:
District:	School:
Class:	Observation time: (start, end)
Observer name:	Number of students:

	Days Preceding				Days Following		
	Day 1	**Day 2**	**Day 3**	**Today**	**Day 1**	**Day 2**	**Day 3**
National or State Standards (in all relevant content areas)							
Learning Objectives							
Activities							
CRED Stage(s) included (see codebook below)							

Science Domain (circle):

Life Science – LS

Physical Science – PS

Earth and Space Science - ESS

Engineering/Science focus:

_____Science content applied in CRED process

_____Science content learned through CRED process

_____ No science content observed during the CRED process

Codebook

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
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
Inclusion of arts/creativity	AC	Open-ended design, connection to Native art, providing art tools for creating designs

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	