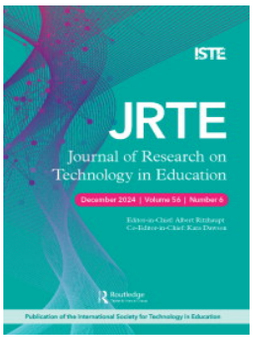

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Culturally-sustaining and revitalizing computer science education for Indigenous students

Jill Bowdon[a], Tia Byers[a], Kathryn M. Rich[a], Marissa Spang[a], Veronica Miller[b], Elena Singer[c] and Amanda LeClair-Diaz[d]

[a]American Institutes for Research, Arlington, Virginia, USA; [b]Arapahoe Schools, Arapahoe, Wyoming, USA; [c]Wyoming Indian Schools, Ethete, Wyoming, USA; [d]Fort Washakie Schools, Fort Washakie, Wyoming, USA

ABSTRACT

Computer science (CS) teachers are still learning how to enact culturally-sustaining/revitalizing CS education for Indigenous students. In response, elementary teachers on the Wind River Reservation, a professional development provider, researchers, and the Wyoming Department of Education formed a researcher-practitioner collaborative to implement and study the implementation of culturally- sustaining/revitalizing CS lessons using design-based implementation research (DBIR) practices. Researchers collected data via interviews, reflection forms, and observations. Findings indicated that teachers used students' funds of knowledge to support engagement and expanded lessons to reflect Indigenous priorities of language revitalization and Tribal sovereignty. Creating culturally-sustaining/revitalizing CS education was a collective activity, drawing on interdependence of teachers and students.

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Introduction

The origin of schooling for Native children involved a deliberate design by the U.S. government and Christian missionaries that forcibly removed Native children from their families and enrolled them in boarding schools. In these schools, Native children's cultures and languages were violently prohibited, which has led to the systematic erasure and endangerment of Indigenous languages and lifeways (Lomawaima & McCarty, 2006). To resist this, the Eastern Shoshone and Northern Arapaho nations have prioritized Indigenous language learning in the public schools that reside on their federally-recognized territory (known as the Wind River Reservation).

One way to prioritize Indigenous language learning is to integrate it with computer science education. Since 2020, educators serving the Northern Arapaho and Eastern Shoshone communities on the Wind River Reservation have been using computer science (CS) education as an additional tool for sustaining and revitalizing their Native cultures and languages—echoing a movement toward using digital technology for cultural revitalization taken up by countless Indigenous communities over the past few decades (Galla, 2016). In focus groups conducted by American Institutes for Research (AIR) in 2020, Eastern Shoshone and Northern Arapaho community members expressed a desire for youth to learn CS in culturally and linguistically

CONTACT Jill Bowdon jbowdon@air.org American Institutes for Research, Arlington, VA, USA

sustaining ways and to use CS to share in cultural traditions, revitalize languages, and support their tribal communities through innovation.

As a result of this interest, school leaders from three elementary school districts on the Wind River Reservation, the Wyoming Department of Education, BootUp Professional Development (PD), and the AIR applied for and received funding from the National Science Foundation (NSF) to form a research-practice partnership called the Wind River Elementary Computer Science (WRECS) Collaborative. To support the districts in reaching this goal, BootUp PD began conducting PD workshops with elementary teachers to support them in learning CS and exploring ways they could integrate CS with instruction focused on Indigenous knowledges and languages. Each PD workshop served as the starting point for an implementation cycle, where teachers implemented lessons in their classrooms and then reflected on the lessons in online meetings. Starting in spring of 2021, the Collaborative began conducting three implementation cycles per year. Although the initial NSF grant concluded in fall 2023, the Collaborative received an additional three years of funding the same fall to continue its work. Currently, the WRECS Collaborative includes teachers and leaders from Arapahoe Schools, Wyoming Indian Schools, and Fort Washakie Schools, as well as the organizations named above and an external evaluator.

Incorporating students' background knowledge, culture, and interests into CS education can support the growth of students' CS understanding and help students recognize how they could contribute to their communities using CS (Kapor Center, 2021). Even so, the CS education field is still learning how to produce and enact culturally and linguistically sustaining and revitalizing CS education, especially for Indigenous students. Consequently, in this article, we report findings from design-based implementation research (DBIR; Fishman et al., 2013) conducted by the WRECS Collaborative. The results presented demonstrate how an asset-based research-practice partnership (RPP) that includes Indigenous communities can contribute to the creation and implementation of culturally sustaining and revitalizing CS teaching and learning for Indigenous elementary students. Further, these findings demonstrate the importance of establishing strong partnerships in bringing about such CS education.

Literature review

We begin with a high-level review of literature related to elementary CS education and culturally sustaining CS education. Next, we draw on a framework for culturally-sustaining/revitalizing pedagogy to highlight key areas relevant to Indigenous communities: revitalization and Tribal sovereignty. Each section highlights the contribution of this paper to the respective body of literature.

Issues in elementary computer science education: Integration and valuing students' identities and cultures

There is growing evidence that children in elementary school can develop understanding of a variety of CS topics such as sequencing and debugging (e.g. Bers et al., 2014; Fessakis et al., 2013). Moreover, teachers often discuss additional benefits of CS education for young students, such as providing opportunities for self-directed and collaborative learning and creating a context where many students find a place to shine and take on leadership roles (Israel et al., 2015).

Even so, researchers have also documented numerous challenges that arise as schools and teachers plan and implement elementary computer science education. Lack of CS-knowledgeable staff is commonly reported as a barrier to computer science education by both administrators and teachers (Wang et al., 2017). Nationwide, most new CS teachers have little or no CS background or training and limited professional development resources (Schwarzhaupt et al., 2021; Yadav et al., 2017).

Integration of elementary CS education with other curricular topics is often discussed as a way of facilitating CS lesson implementation by teachers new to CS because it draws on teachers' knowledge of the integrated topics (Rich et al., 2019). The WRECS Collaborative adapted this integration strategy to center Indigenous languages in CS lessons. Integration of CS into the schools' existing programs for teaching Indigenous languages and knowledges to Northern Arapaho and Eastern Shoshone youth provided an opportunity to leverage the valuable and vital knowledge of Indigenous teachers in support of teaching students CS.

Integration of CS with Indigenous knowledges and languages in the WRECS Collaborative also created opportunities to emphasize the cultural heritages students bring to the classroom as central to their computer science experiences, thereby ensuring that: *…students' interests, identities, and cultures are embraced and validated, students develop knowledge of computing content and its utility in the world, strong CS identities are developed, and student engage in larger socio-political critiques about technology's purpose, potential, and impact (Kapor Center, 2021, p. 5)*

The CS education field as a whole is still grappling with how to create CS education experiences that will accomplish these goals for students from all backgrounds and cultures, in both elementary school and elsewhere (e.g. Lachney et al., 2024; White et al., 2024).

Access and enrollment data illustrates a particular need to explore how to implement CS in ways that embrace and value Indigenous students' identities and cultures. Code.org's (2023) Computer Science Annual Access Report showed that American Indian/Alaskan Native students, in comparison to their peers, attended high schools that offered computer science at the lowest rate (67%) compared to White (82%) and Asian (89%) peers. Even more, American Indian/Alaskan Native high school students are underrepresented in their enrollment in a foundational CS course compared to their population, while White and Asian students are overrepresented.

In this paper, we discuss the WRECS collaborative as a setting for exploring how to implement CS education in ways that value the assets and uplift the goals of Indigenous communities–echoing a movement toward using digital technology for cultural revitalization taken up by countless Indigenous communities over the past few decades (Adcock, 2014; Galla, 2016). To provide further context to frame this work, we next discuss a pedagogical framework developed specifically to attend to Indigenous community priorities.

Centering Indigenous priorities through culturally-sustaining/revitalizing pedagogies

There is an abundance of literature that critiques the assimilative, violent nature of Western schooling on/in Indigenous communities, as well as a call for culturally-responsive schooling (CRS) for Indigenous children (Castagno & Brayboy, 2008). In line with CRS, culturally-sustaining/revitalizing pedagogies (McCarty & Lee, 2014) is an approach that has been used to reclaim school-based learning for American Indian and Alaska Native students directly in schools and in the literature. Culturally-sustaining/revitalizing pedagogies builds on culturally sustaining pedagogies (Paris & Alim, 2017), which "seeks to perpetuate and foster—to sustain—linguistic, literate, and cultural pluralism as part of schooling for positive social transformation" (p. 1). Three distinct characteristics make up culturally-sustaining/revitalizing pedagogies. Foremost, use of culturally-sustaining/revitalizing pedagogies is a way to enact Tribal education sovereignty. These pedagogies contest the power that federal and state governments have over factors like educational standards, curricula, and content and, instead, assert the authority of Indigenous peoples and schools to determine the content and approaches to education for their youth. Secondly, culturally-sustaining/revitalizing pedagogies aim "to reclaim and revitalize what has been disrupted and displaced by colonization," including the centrality of reclaiming Indigenous mother tongues as an expression of Tribal education sovereignty (McCarty & Lee, 2014, p.103). Because western education has violently prohibited Indigenous languages and culture, there is

a pressing need for Indigenous-serving education to re-energize and center the study of Indigenous language. This focus on revitalization will strengthen connection to and understanding of Indigenous language. Thirdly, culturally-sustaining/revitalizing pedagogies are grounded in community accountability, which attends to the values and goals as defined by an Indigenous community (McCarty & Lee, 2014).

Culturally-sustaining/revitalizing pedagogies have been used by a number of Indigenous communities to teach and learn Indigenous languages in school-based dual-language and immersion settings (Tedick & Lyster, 2019). What is less understood is the application of culturally-sustaining/revitalizing pedagogies in teaching and learning CS in school settings with American Indian/Alaska Native students. While several research-practice collaboratives and studies have supported teachers of Indigenous youth to create culturally responsive CS experiences (e.g. Biin & Weston, 2015; Kafai et al., 2014; Yan et al., 2024), most have focused on middle or high school and there has been less attention to elementary grade students. This is not to say that culturally-sustaining/revitalizing pedagogies in CS teaching and learning are not happening with and by Indigenous communities in and out of school, but rather that the literature has not kept up with lived practice. This presents an opportunity to introduce an example of culturally-sustaining/revitalizing pedagogies in CS education to the literature, in the current paper. We build on the existing literature through our work in the elementary space. Moreover, our work responds to a call by Yan et al. (2024) to examine how to provide more CS professional development—beyond a one-day or one-week workshop—to teachers of Indigenous students in ways that support both teachers' and students' ongoing development. We describe the ongoing professional learning in the next section.

Study setting and context

The findings reported in this article are situated within a broader project that included initial focus groups with the Eastern Shoshone and Northern Arapaho communities, curriculum development, and cycles of professional development and lesson implementation with elementary teachers. We briefly describe these activities here to provide context for interpreting the findings.

Meeting with business councils

At the project's onset, researchers presented to governing bodies, or Business Councils, for the Eastern Shoshone and Northern Arapaho tribes on the Wind River Reservation to ask for their permission to engage schools, educators, and community members in the project. Both Business Councils gave their blessings for the work to take place and asked researchers to share progress updates.

Focus groups

Soon after the WRECS Collaborative received grant funding from NSF in 2019, researchers facilitated focus groups to learn more about the strengths of communities on the Wind River Reservation and the ways in which the Eastern Shoshone and Northern Arapaho communities sustain and revitalize their cultures, languages, and histories in the context of formal schooling and in the community. Each focus group was hosted by one of the three school districts on the Wind River Reservation (Arapahoe Schools, Fort Washakie Schools, and Wyoming Indian Schools) in February 2020. A total of 28 participants—including district and tribal leaders, teachers, and families whose students attended the schools—attended the focus groups. Analysis of themes from the focus groups showed that Eastern Shoshone and Northern Arapaho community members on the Wind River Reservation find strength and pride through cultural engagement and sustaining their ancestral languages. From the perspective of the community, CS education could

prepare students to serve tribal communities by pursuing postsecondary pathways involving coding. Furthermore, some cultural knowledge is sacred and off-limits for those outside of the tribes, meaning that it should not be shared with the public or represented in project artifacts. After the focus groups, researchers prepared memos containing the findings to share with each school community synthesizing what they had learned about community strengths and priorities. These focus groups were a key part in establishing a positive relationship between researchers and community members because they demonstrated the researcher's desire to center community-identified priorities and to take a strength-based approach. The focus groups also provided an opportunity for explicit discussion about sharing collective credit for research findings and making research mutually beneficial. As a result, researchers engage in a process of checking the interpretations of findings with community members prior to any publication. Furthermore, researchers ensure that presentations and publications sharing results from the study always include community members as co-presenters, coauthors, and reviewers.

Curriculum development

To respond to the expressed desires of teachers and community members, BootUp PD—one of the Collaborative's organizational members—created examples of elementary CS lessons that taught age-appropriate CS concepts and were rooted in teaching cultures, histories, and languages of the Eastern Shoshone and Northern Arapaho. Students created projects in Scratch, a free and commonly used web-based platform for teaching computer science through drag-and-drop coding. For example, in one lesson Eastern Shoshone students used Scratch to animate the letters in the name of a famous historical figure in their tribe—Chief Washakie—so that clicking on each letter of the name provided additional information about his life. For more information about the curriculum development process, see Wilson et al. (2023). Table 1 summarizes additional lesson examples and Figure 1 depicts an example of a Sprite—or character—from Scratch.

Professional development and lesson implementation

BootUp PD also supported the three participating districts by providing professional development (PD) aimed at increasing teachers' pedagogical and content knowledge related to CS. The

Table 1. Examples of lessons integrating CS with Indigenous history, culture, and language.

Lesson title	CS content	Culturally sustaining/revitalizing content
Interactive Collage	Students use simple algorithms to create an interactive collage that describes some of the people, places, and things in their lives when a sprite is clicked.	Students discuss their own interests and cultural backgrounds.
Historical Timeline Remix	Students learn to sequence code blocks.	The sequence is determined by a timeline of the history of the Wind River Reservation.
Introducing a Historical Figure	Students program two characters to talk to each other and act out an interview.	Interviews are with historical figures such as Chief Washakie.
Virtual Museum	Students collaboratively research and code an interactive environment that simulates visiting a museum.	Museum items relate to Eastern Shoshone and Northern Arapaho history and culture.
Interactive Digital Artifact	Students decompose an image to create an interactive artifact that responds when different parts are clicked.	An example project turns an image of a buffalo into an interactive artifact that provides information about how Northern Arapaho and Eastern Shoshone people use different parts of the animal.

Note: A Sprite is a character in the Scratch programming environment that can be coded move or speak.

Figure 1. An example of a Sprite in the Scratch programming environment.

Table 2. Timeline of RPP activities.

Project year	School year	RPP activities
1	2019–2020	• AIR conducts community focus groups • BootUp PD develops example CS lessons
2	2020–2021	• Pause due to COVID-19 pandemic
3	2021–2022	• BootUp PD delivers 3 PD workshops • Teachers implement CS lessons in the classroom • AIR facilitates 3 PLC meetings • AIR observes PD, conducts interviews, and collects feedback and reflection forms
4	2022–2023	• BootUp PD delivers 3 PD workshops • Teachers implement CS lessons in the classroom • AIR facilitates 4 PLC meetings • AIR observes PD, conducts interviews, and collects feedback and reflection forms

professional development focused on instructing teachers how to use Scratch with students in their classrooms.

Two cohorts of teachers participated in professional development, implemented lessons, and provided data on their experiences. Starting in the 2021–22 school year (cohort 1), teachers in the three participating districts used their existing expertise to adapt and enhance the example BootUp lessons to meet their needs and to explore different ways to implement them in their classrooms. AIR facilitated virtual professional learning community (PLC) meetings between professional development workshops, where teachers discussed their successes and challenges in implementation and shared their lesson ideas. The Collaborative referred to each cycle of one professional development, implementation of lessons in classrooms, and one or two PLC meetings as an implementation cycle. We used these implementation cycles to conduct DBIR about the Collaborative's experiences.

In the 2022–23 school year (cohort 2), a mixture of the returning and new teachers in the Wind River Reservation schools participated in PD and PLCs and implemented CS lessons. A timeline of the RPP activities across the four years of the project is included in Table 2.
In this article, we summarize the results of the research conducted by members of the RPP as across the four years of the project. What emerged over time was how Indigenous teachers reclaimed the Scratch platform to teach and learn Indigenous languages, alongside coding.

Positionality

The author team for this study includes Collaborative members from the research organization and from all three participating districts. The research representatives are four women—one Indigenous (Northern Cheyenne and Crow), one African American, and two White. Two have teaching

experience, and all have expertise in education research and two or more years of experience working specifically with the communities on the Wind River Reservation. Collectively, we are committed to centering the voices of our Indigenous partners and their ingenuity and solutions within this work.

The district representatives are three Indigenous women—one Eastern Shoshone and two Northern Arapaho—who live and work in the communities on the Wind River Reservation. They wished to share the following information about themselves and their communities:

> Wyoming Indian Schools is located in the community of Ethete where students attend from all surrounding communities on and off the Wind River Reservation. Wyoming Indian Schools offers Indigenous Language classes Pre-K through twelfth grade. The Wind River Computer Science Collaborative provides another opportunity for teachers and students to learn and use Indigenous Languages in a digital setting which reinforces and affirms Indigenous language inquisition. My role was to connect and share resources with teachers to collectively move our Indigenous Language efforts forward through student coding.

> When I was growing up, my parents told me about how the Eastern Shoshones have always revered the Wind River Mountains. This connection between us and the mountains is present in our community today. My mother, an educator, always expressed to her students how our mountains are precious (LeClair-Diaz, 2022). They take care of us so in turn we have to take care of them. At Fort Washakie Schools, the Wind River Mountain range is in clear view of our district and serves as a constant reminder of the importance of reciprocity. It is a landmark that is present in the students', their families', and the staff members' lives. Our student body is predominantly comprised of Native students who identify as Eastern Shoshone, Northern Arapaho, and/or other tribes (i.e. Crow, Northern Cheyenne, Lakota, Navajo, etc.). What remains ever present is the reverence we have for our mountains and in taking care of them, we are also taking care of everyone in our community and the surrounding areas.

> I am the Director of Federal Programs and Indian Education for Arapahoe Schools. Our Mission at Fremont County School District #38 *empowers students to acquire a rigorous education through effective academic instruction, becoming fluent Hinonoʼeitiit speakers who encourage a strong identity and to embrace their cultural heritage that builds on their resilience to flourish in an ever-changing world.* We are located in Central Wyoming on the Wind River Indian Reservation which is comprised of the Eastern Shoshone and Northern Arapaho tribes. There are three distinct communities; Fort Washakie, Ethete and Arapahoe. Our school is located in Arapahoe and the population of students are primarily "Arapaho" with less than 10% of other tribal affiliations.

Research questions

This study addressed three research questions:

1. What challenges arise when elementary school teachers implement lessons that integrate CS and Indigenous language and culture?
2. How did elementary school teachers adapt and enhance lessons that integrate CS and Indigenous language and culture?

According to teachers, how did Collaborative activities support students' engagement and development?

Methodology

We addressed these questions by incorporating elements of design-based implementation research (DBIR) into our project design and methodology. DBIR practices are guided by the four principles listed in Table 3 (Fishman et al., 2013). Table 3 describes how the four principles of DBIR informed our methodology.

Sample and data collection

Two cohorts of teachers participated in the WRECS Collaborative. The first cohort included 11 teachers which the second cohort included 19 teachers. The grades and subjects taught by our participants is listed in Table 4.

Table 3. Wind River Elementary CS's incorporation of DBIR principles.

DBIR principles	Implementation of DBIR principle in the WRECS collaborative
A focus on persistent problems of practice from multiple stakeholders' perspectives	Community members, families, teachers, the Wyoming Department of Education, curriculum developers, and professional development providers contributed to defining the problems of practice through community focus groups, conversations, feedback surveys, and lesson reflection surveys, and interviews. The focal problems of practice were challenges that arose as teachers planned and implemented culturally-sustaining/revitalizing CS education.
A commitment to iterative, collaborative design	The Collaborative iterated on the design, content, and approach to professional development and professional learning communities based on feedback from professional development providers, curriculum developers, teachers, and researchers. Iterative improvement occurred between each of the three implementation cycles for each cohort and across project years.
A concern with developing theory and knowledge related to both classroom learning and implementation through systematic inquiry	The Collaborative developed and tested theory around the design and enactment of culturally-sustaining/ revitalizing CS education.
A concern with developing capacity for sustaining change in systems	The Collaborative built an infrastructure for sustainability in our implementation. For example, our professional development sessions are focused on incorporating computer science and culturally-sustaining/ revitalizing materials into the teachers' existing curriculum, allowing for teachers to use materials after the end of the project.

Table 4. Counts of participating teachers by cohort and grades taught.

		Teachers				Para-educators	STEM	Indigenous Language/ Studies
	Overall	PreK	K-5th	6–8th	9–12th	PreK–8th	PreK8th	PreK–8th
Cohort 1	11	0	3	2	1	3	2	0
Cohort 2	19	2	3	4	1	3	3	3

Note: Cells represent counts. Participants self-identified their grades and subjects. Some participants were teachers and others were para-educators, STEM or STEAM educators, or Indigenous Language/Studies educators. Consolidation of subjects and grades due to wide variation of participant self-identification.

Table 5. Counts and percentages of teachers who participated in data collection by cohort.

	Overall N	PD 1	PD 2	PD 3	PLC 1	PLC 2	PLC 3	Lesson reflection form	End of year interview
Cohort 1	11	10 (91%)	10 (91%)	5 (46%)	7 (64%)	7 (64%)	6 (55%)	10 (91%)	7 (64%)
Cohort 2	19	16 (84%)	12 (63%)	12 (63%)	17 (89%)	13 (68%)	16 (84%)	15 (79%)	16 (84%)

Note: N represents the overall count of participants in each cohort. PD refers to professional development sessions. PLC refers to Professional Learning Community sessions. The numbers in each cell detail the number of participants who attended PD or PLC sessions/submitted lesson reflection forms/participated in interviews. The percentages in parenthesis refer to the participation rate in each data collection activity.

The count and percentage of teachers who participated in the different data collections is listed in Table 5. Data collection included interviews with teachers, observations of professional development, teacher feedback and reflection forms completed post-professional development and lesson implementation respectively, and end-of-year participant interviews. Teacher interviews occurred in spring of 2022 and 2023. The other data were collected across the 2021–2022 and 2022–2023 school years.

Analysis of the teacher interviews drove the data analysis process for this article. Our thematic analysis of interview data utilized both inductive and deductive coding (Braun & Clarke, 2006). AIR analyzed end-of-year interviews from 2021 to 2022 using deductive coding based on three categories stemming from the research questions: *challenges* encountered during implementation (operationalized as problems of practice; Henriksen & Richardson, 2017), *adaptations* teachers made to the BootUp sample lessons as they planned and implemented

in them in their own classrooms, and *enhancements*, which we defined as activities and lessons made by teachers that went beyond the originally envisioned scope of the Collaborative. Then, AIR developed inductive categories of common challenges, adaptations, and enhancements. Researchers used these categories to create a codebook for the interviews from 2022 to 2023 and coded those interviews. After all interviews were coded, AIR did a frequency analysis to explore the common challenges, adaptations, and enhancements between both cohorts of participating teachers. Researchers reviewed all excerpts related to each code to develop analytic summaries related to common challenges, adaptations, and enhancements applied across the two teacher cohorts.

Upon review of coding output, AIR identified two codes that more closely related to teacher reflections about student competencies than to challenges encountered by teachers or action steps teachers took. Researchers developed research question 3 based on these codes and summarized teacher comments related to each code.

To finish the analysis, researchers reviewed the analytic summaries of each code and collaboratively developed two themes to describe and connect the ideas across codes and research questions. AIR reviewed other data sources (memos from observations, teacher feedback forms, and teacher reflection forms) to identify any information that corroborated or contradicted each theme. Any identified corroborating or contradictory evidence was incorporated into the findings to enrich the analyses (Freeman et al., 2007). Members from both the Eastern Shoshone and Northern Arapaho checked interpretations of results to ensure their integrity and accuracy and researchers responded to their written and oral feedback by revising drafted findings.

Results

Teachers participating in the WRECS Collaborative reported encountering several challenges related to meeting students' needs as they taught integrated Indigenous studies and computer science (research question 1). However, teachers overcame many of these challenges by adapting and enhancing the lessons to make them more culturally-sustaining/revitalizing and to construct a learning environment that affirmed students' identities (research question 2). Students also contributed to successful lesson implementation by using their culture and backgrounds as resources (research question 3). These initial findings are illustrated by the coding summary in Table 6.

Table 6. Coding summary of teacher interview data aligned to research questions.

RQ and high-level code	Subcode and description	Number of teachers with interview excerpts coded with subcode
RQ1: Challenges	Engagement: Difficulties generating or maintaining student interest in CS	6
	Lack of CS knowledge: Not knowing enough CS to guide students through projects	7
	Lack of Indigenous knowledge: Not knowing enough about Indigenous languages and knowledges to support student learning of these topics	5
RQ2: Adaptations and enhancements	Activating funds of knowledge: Connecting lessons and projects to students' backgrounds, hobbies, and heritages	16
	Collaboration with teacher peers: Working with colleagues to plan and teach lessons	14
RQ3: Student benefits	Showcase for student strengths: Students grew in their presentation and leadership capabilities	7
	Collaboration among student peers: Students helped each other as they created CS projects.	8

Note: RQ stands for research question. Teachers who mention a challenge, adaptation, or benefit in more than one interview (i.e. a teacher who participated in both implementation years and was interviewed at the end of each year) are only counted once in each row. The total number of unique teachers who participated in interviews across years was 20.

We organize elaboration of these findings around two themes that weave together codes related to each research question (RQ): how teachers used students' funds of knowledge to support student engagement, and the ways in which culturally-sustaining/revitalizing CS education became a collective, interdependent activity. Under each theme, we discuss challenges discussed by teachers, how teachers' adaptations and enhancements led to instruction that reflected culturally-sustaining/revitalizing pedagogy, and related benefits to students.

Theme 1: elementary teachers tapped into Indigenous students' funds of knowledge to support their engagement in CS lessons

Challenges

In interviews and during professional development, six teachers shared challenges related to supporting student engagement. These teachers (and three additional teachers) said that students were engaged once they got started with coding. Indeed, three teachers of some of the youngest students (PreK-grade 2) said their students were so excited to code that it was a struggle to get them to wait for instructions. However, six teachers explained that their older students (grades 3–6) were reluctant to start. Some students found past activities with Scratch repetitive and boring. Other students did not immediately grasp what coding was or was for.

Culturally-sustaining/revitalizing CS pedagogy

Sixteen teachers activated students' "funds of knowledge"—or knowledge gained outside of school that is needed to thrive in one's home and community—as a tool to engage and support students with new content and create a culturally-sustaining/revitalizing and identity-affirming environment (Ladson-Billings, 1995; Moll & González, 1994). In this study's setting, students' funds of knowledge included everyday aspects of youth recreation in their community (e.g. basketball, video games, YouTube), but also, importantly, the language, stories, and cultural traditions of their tribes.

As an example of how teachers activated students' funds of knowledge about CS by making connections related to day-to-day life, one sixth-grade teacher reported starting a conversation with students about technology that they use every day—like Google Classroom—and talking about how computer programming makes the technology run. Two other teachers reported more explicit connections between what students would be doing in the Scratch platform and student hobbies. In the project-provided lessons, students were using block-based coding within Scratch to make images or characters—known in Scratch as sprites—move across the screen and talk. One teacher, who taught students across K-5, made connections between what students observed sprites doing and what they have seen in video games, which the students loved to play and discuss. Another sixth-grade teacher first allowed her students to explore video animation and then helped them understand how this animation resulted from computer coding. These connections eased the transition into using the block coding in Scratch because students were motivated to learn.

Like district leaders who participated in the focus groups, teachers saw computer science not only as an instructional tool for meeting academic standards, but as a tool for revitalization of Indigenous languages and histories and for students to explore and grow their Indigenous identities. One district leader described the lessons developed through the RPP as teaching "Indigenous studies through computer science," succinctly illustrating their prioritization of Indigenous studies and identity development in the lessons. A second district leader described the WRECS Collaborative as creating a digital space for teachers and students to learn and grow in the Indigenous languages. The districts' work in Indigenizing Scratch affirms that, "Indian communities have established a pattern of appropriating Western technologies to recover and preserve their linguistic traditions" (Adcock, 2014).

As an example, the rich use of CS to support revitalization of Indigenous knowledges, one team of teachers centered their lesson around a cultural story and encouraged students to imagine how they would direct a sprite to complete the actions in the story. This activity engaged Kindergarteners in thinking through the story in a new way, supporting deeper engagement with the cultural content. For a coding lesson in Scratch, a STEM specials teacher reported using "Symbols and patterns that are meaningful to the students. It was individualized…but a lot [of students] picked indigenous patterning and colors." Using the Scratch platform to incorporate Indigenous art, stories, and languages that were meaningful to the students helped them understand the relevance and potential of coding while also allowing teachers to establish a culturally-sustaining/revitalizing and identity affirming environment (Ladson-Billings, 1995; McCarty & Lee, 2014).

Benefits to students

Overall, teachers across cohorts believed that taking the time to build a multilayered understanding of coding and how it connected to the students' Indigenous cultures and community paid off because it resulted in higher student engagement and interest. District leaders and teachers saw a high level of engagement and creativity throughout the Scratch lessons with the incorporation of Indigenous languages. Students understood the purpose of learning about CS because they understood how it could interplay with their current and future worlds. Teachers helped students acquire new knowledge of CS concepts while also expanding their sense of the potential role CS could play in their future lives and communities. Students expanded their understanding of how block-based coding worked and encountered new vocabulary like "algorithm" and "loop" while working to gain mastery of CS standards. Because teachers had invested time in connecting the CS lessons with students' daily experiences, students were able to see how coding could play a role in potential career pathways and why they might want to acquire this skill set.

Moreover, teachers noted that the CS projects were a new way to showcase student strengths. Students enjoyed giving presentations about their coding projects to their peers and teachers, and some students even presented their projects to parents at student-led conferences and to school board members at a board meeting. These presentations allowed teachers to learn more about their students and what they are interested in. Seven teachers noted they were particularly pleased with how the integrated projects allowed students who are typically less engaged in school to have their moments to shine. These comments echo findings from Israel et al.'s (2015) cross-case analysis of a computing initiative at one elementary school, where students who were typically characterized as "struggling learners" tended to thrive during computing instruction and even take on leadership roles in supporting their peers. The emergence of a similar finding in this study suggests that creating culturally-sustaining/revitalizing CS projects like those created by the WRECS Collaborative may be a productive strategy to help unlock the potential of CS to engage all students in school-based learning.

Theme 2: culturally sustaining/revitalizing CS education was a collective activity, with interdependence among teachers and students

Challenges

Some of the challenges WRECS teachers mentioned highlighted the need for connections among contributors (e.g. teachers and students) to support creation of culturally-sustaining/revitalizing CS education. For example, seven teachers cited their lack of CS content knowledge as a barrier they needed to overcome to feel confident to teach computer science lessons, similar to other work (e.g. Wang et al., 2017). Five teachers in the Collaborative expressed discomfort or worry about planning and implementing Indigenous studies through CS lessons because of their limited knowledge of Indigenous languages and histories. While some teachers participating in the

Collaborative were Eastern Shoshone or Northern Arapaho, some were not members of those tribes. They were concerned they could not support students to, for example, express ideas in Indigenous languages and so felt reluctant to implement CS projects that incorporated Indigenous language without additional support from language experts.

Culturally-sustaining/revitalizing pedagogy

For these reasons, implementing culturally sustaining/revitalizing CS education was a group effort among teachers. Sixteen teachers reported partnering with same-grade peer teachers and specialists to adapt lessons in ways that would meet their grade-level standards and students' needs. This collaboration on lesson planning and implementation was not part of the program design; rather, teachers embraced it independently. As one teacher reported, *"I don't know if I could have done this on my own, I probably would've overwhelmed myself. But being able to work with someone who kind of already knew how to do it and was able to show me and help me along the way…was really helpful."* Collaborating with peers made implementing the CS content easier but it also facilitated adaptation of lessons to be culturally-sustaining/revitalizing. Not all teachers shared culture or language with their students. Indigenous language or resource specialists helped classroom teachers adapt lessons so that they could use students' Indigenous language to teach content—like the human circulatory system—within Scratch.

Benefits to students

Indigenous elementary students were also contributors to planning and implementing lessons, which was helpful for teachers and also created opportunities for students to learn new skills and explore their identities. Students contributed in meaningful ways to the projects they created, both in terms of instructional and technical support for teachers and other students and in terms of infusing personally meaningful content into the projects.

Relating to instructional and technical support, teachers explained that the integrated projects supported peer collaboration and learning amongst students. Eight teachers noted that as students worked in Scratch, they were eager to help each other and became more independent of teacher intervention. This finding suggests two important phenomena in elementary computer science education settings that occur with/by Indigenous communities. First, a critical facet of an Indigenous pedagogy is that it positions teachers and students as having shared responsibility in learning activities or contexts, where the teacher-student roles are fluid. This fluidity allows for students to illustrate their expertise and share that knowledge with peers and adult teachers, as well as their ability as capable practitioners—and they are believed for what they know and practice (Peltier, 2021; Simpson, 2014). This approach was embraced by several teachers and can be observed in one teacher's statement where they shared, *"I feel like it's a little bit inquiry-based as you're moving through Scratch, because you don't want to just give them the answer. You want to challenge them to figure out the answer by asking them the right questions. But sometimes, you can't really plan the questions you're going to ask them because all the challenges are different for the students."*

Second, the coding projects created and implemented by the WRECS Collaborative teachers fostered a key computer science practice: Collaboration around computing (K-12 Computer Science Framework, 2016). The K-12 Computer Science Framework outlines expectations that by the end of high school, students should be able to cultivate working relationships with others to work together on creating computational artifacts and solicit and incorporate feedback from diverse perspectives. WRECS Collaborative teachers noticed students sharing their knowledge and supporting each other while creating Scratch projects, thereby building foundations for collaborations on more complex artifacts in middle school and high school. Together, the Indigenous pedagogy and student collaboration that teachers facilitated supported a model of peer-mediated learning that also made instruction and classroom management easier for teachers than it would have been otherwise.

As examples of students making personally meaningful content contributions to the projects, one third-grade teacher reported having students tell stories of their own lives using Scratch. The teacher stated that "*…what they did was they had to program themselves as a sprite [an animated character or object programmed in the Scratch platform] and then talk about their family… And it was cool because you got to see, 'This is my grandpa who taught me these things, and this is my aunt who taught me these things. And I learned a bead working from this person.' And all of that was on display in the Scratch.*" The same teacher also reported using Scratch to focus on Arapaho words. Specifically, he asked his students to choose a favorite word in English, then translate that word into Arapaho. Students coded a Scratch project that spelled the word in Arapaho, with each letter coded to illustrate something about why the word was the students' favorite. Students also practiced pronouncing the word and recorded themselves saying it, using the recording function in the Scratch project. This activity allowed prolonged exploration of a word in Arapaho that was closely connected to students' interests. As the teacher commented, *"I'll bet a lot of the students who did our projects know those words now because they had to speak it a couple times, they had to think about it. I think that that was really powerful to help them learn their culture more and to be able to express who they are through the Scratch project. I think that that is huge."*

Discussion

The article, including the discussion, purposely centers the ingenuity and education sovereignty enacted by teachers and students—an intentional framing as it recenters "Indigenous educators' strategic use of schooling as the driving action…a retelling that challenges settler colonialism's exclusive claim on schools" (McCoy & Villeneuve, 2020, p. 488). This study advances the field's understanding of development and implementation of culturally-sustaining/revitalizing CS education at the elementary level. Findings indicate that combined efforts of curriculum developers, professional development providers, teachers, students, families, and community members can produce culturally-sustaining/revitalizing CS education. The collective and iterative process of creating culturally sustaining/revitalizing CS education implies that everyone has a role to play and that the lessons are never static or complete. Moreover, the critical role of the teachers and students in designing and enacting the lessons illustrates how the Eastern Shoshone and Northern Arapaho communities used the WRECS collaborative activities as a context for exercising educational sovereignty, revitalizing Indigenous languages, and enacting community accountability—the three components of the culturally-sustaining/revitalizing framework (McCarty & Lee, 2014).

In this study, community members and families expressed the desire for additional opportunities for their students to learn CS concepts in ways that incorporated and enhanced students' knowledge about their Indigenous histories, cultural traditions, and languages. These expressed desires motivated BootUp PD to design lesson plans that could be tools for accomplishing these aims. BootUp PD produced and introduced lesson plans that integrated CS and Indigenous languages and knowledges and provided professional development.

Through the professional development, BootUp PD empowered teachers to adapt lessons and to envision applications that went beyond provided examples. Teachers adapted and enhanced these lessons to build a culturally-sustaining/revitalizing environment for students that activated their students' strengths as resources in the classroom. Before starting CS lessons, teachers engaged students by helping them make connections to their Indigenous cultures, languages, and everyday lives. Teachers facilitated connections between activities that students valued–like video games or animation—and CS, as well as connections between how learning CS can address societal issues, like underrepresentation of Indigenous voices in the CS industry. These connections helped establish the purpose of the instruction as expressed and enacted by the Tribal communities, and not merely by state agencies providing oversight on what was to be taught (McCarty & Lee, 2014).

Once teachers established a culturally-sustaining/revitalizing and identity affirming environment, they were equipped to bridge the known to the new. They taught new CS concepts like algorithms and loops in the context of lessons about Indigenous stories and art. They used the Scratch lessons to support Indigenous language revitalization (as described by McCarty & Lee, 2014) by incorporating Indigenous words or phrases into instruction and projects. When teachers did not share a cultural or linguistic background with students, they overcame this challenge in two ways: by collaborating with colleagues that did share a cultural background with their students and by creating CS projects that provided teachers with windows into their students' backgrounds and interests.

Perhaps most importantly, students engaged their brilliance to imbue projects with their interests, strengths, background knowledge, and values. Teachers relied on peer-to-peer support as a mechanism for meeting different needs of their students—embodying the community accountability inherent to the culturally sustaining/revitalizing framework (McCarty & Lee, 2014). Some students required more help, while others were able to serve as leaders or helpers within their classroom. Furthermore, students made projects their own and highlighted their talents for their families and communities. Based on this finding, curriculum developers and teachers can consider involving students in the creation of culturally-sustaining/revitalizing approaches by providing opportunities for student-led exploration and peer-to-peer collaboration. Administrators in schools and districts can embrace students voice by creating opportunities for them to showcase their strengths to their families and communities. Treating students' backgrounds and existing knowledge as assets and resources flips the paradigm of students being receivers of curriculum to being co-creators and experts.

In addition to these generally applicable implications of study findings for producing and enacting culturally sustaining/revitalizing CS education, the findings also have specific implications for those working to broaden access to CS education for Indigenous communities and youth. CS has exciting potential to serves as a tool for sustaining and revitalizing Indigenous cultures, values and languages with/by Indigenous communities. Students may find applications of CS education exciting because of their involvement with youth's everyday computing culture (e.g. video games, animation, Indigenous language). Teachers can leverage this excitement to introduce CS concepts to students.

When supported with culturally sustaining/revitalizing pedagogies and activities, students can apply coding skills in ways that simultaneously reclaim their Indigenous cultures and languages and enhance their understandings and practices of CS. If given the opportunity to share their applications with their families and communities at events, students become the experts or "teachers" and have the potential to play a valuable role in sustaining and revitalizing Indigenous languages and values in their communities. Both the production of projects and engagement with community can allow students to envision future, potential selves that use CS in ways that empower and serve their communities.

Limitations

We conclude by acknowledging limitations of the study. First, the study occurred during the COVID-19 pandemic and resulting disruptions to schooling, which had dramatic negative impacts on the health and wellbeing of community members on the Wind River Reservation. This context might have impacted teachers' experiences with the professional learning and what they reported as challenges, adaptations, or enhancements. Second, the findings discuss the importance of student voice and agency, and teacher data suggests that student engagement improved as a result of the activities described here. However, this study did not collect data about student perspectives and experiences. For a project like this one that fundamentally seeks to strengthen student connection and engagement, this is a limitation. Future studies should consider mechanisms for incorporating student focus groups, interviews, surveys, and Indigenous and participatory research.

Implications and future directions for research

This study has potential implications for those interested in broadening participation in CS education for students that have historically been underserved—including, but not limited to, broadening participation in CS in Indigenous communities. Teachers face challenges when tasked with implementing culturally sustaining/revitalizing CS content or curricula. Challenges may include developing ways to engage students meaningfully. Other challenges relate to teachers' knowledge of CS and students' culture and language. This study's findings demonstrate how teachers adapted and enhanced CS lesson plans to address challenges they faced during implementation and to increase the extent to which lessons were culturally sustaining/revitalizing. These adaptations and enhancements can serve as springboards for teachers nationally who are grappling with similar concerns. Future research on culturally sustaining/revitalizing CS education could include Indigenous students' voices to enhance understandings of implementing Indigenous pedagogies, values, and everyday computing experiences and perspectives.

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Notes on contributors

Jill Bowdon is a Principal Researcher at the American Institutes for Research, where she leads research on educators and instruction with a goal of generating evidence and centering voices of teachers, students, and families. She began her career as a fourth-grade teacher.

Tia Byers is a Research Associate at the American Institutes for Research (AIR). Her work at AIR focuses on educational equity and access in K-12 education through issues in computer science and STEM. She seeks to engage in research that uplifts the ingenuity and voice of marginalized communities.

Kathryn M. Rich is a senior researcher at the American Institutes for Research, where she leads projects in computer science and mathematics education. She continually seeks to conduct research that highlights the brilliance and dedication of both educators and students.

Marissa Spang (Northern Cheyenne and Crow) is an Indigenous Education Researcher at American Institutes for Research. In all work, she employs Indigenous and Western research methodologies in ways that are consensual to Indigenous worldviews and center lived and storied Indigenous STEM+CS learning settings for/by Indigenous students.

Veronica Miller is currently the Director of Federal Programs & Indian Education at Arapahoe Schools. She has been an educator for 30+ years. She has served most of her career on the Wind River Reservation and is a member of the Northern Arapaho Tribe. She is largely devoted to the revitalization of the Hinono'eitiit, aided the state in developing Wyoming's Indian Education for All, and advocates on a National level for Indigenous Education.

Elena Singer is a Northern Arapaho/Oglala Lakota educator and is the director of the Language and Culture Department of Wyoming Indian Schools on the Wind River Reservation in Central Wyoming. She advocates for and seeks opportunities to Indigenize education and support Indigenous Language revitalization in schools.

Amanda LeClair-Diaz (Eastern Shoshone/Northern Arapaho) is the Indian Education Coordinator at Fremont County School District #21 which is located on the Wind River Reservation. She works on curriculum development with Indigenous language teachers and community efforts in language revitalization and culture events.

ORCID

Jill Bowdon http://orcid.org/0000-0002-6299-5141

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