

Rural Teachers' Cultural and Epistemic Shifts in STEM Teaching and Learning

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This article focuses on the ways in which integrated curriculum can improve STEM teaching and learning within rural spaces. Using a design-based research approach, this study focuses on rural teachers' experiences of professional learning and development training as they learn to engage computing and maker technologies in their elementary classrooms as tools for teaching students about difficult histories of immigration, migration, and forced relocation across the United States.

Keywords: rural education, STEM, social studies, design-based research

Meaningful experiences with science, technology, engineering, and mathematics (STEM) help students develop strong STEM identities that support their further interest and academic performance (DeWitt & Archer, 2015; Tan et al., 2013). An important part of sustained interest in STEM opportunities for K-12 students is a sense that “people like them” engage legitimately in STEM disciplines. For example, Archer et al. (2010) found that even students with active interest in STEM and strong academic achievement in STEM courses may feel that their identities are incompatible with full participation over time. Such perceptions of identity incompatibility may span race, gender, and socioeconomic class (Archer et al., 2010, 2012; Carlone & Johnson, 2007). Accordingly, effective educational strategies for building equitable pathways to STEM participation over time requires the opportunity for students' diverse identities to be meaningful and legitimate aspects of classroom STEM activities (Calabrese Barton & Tan, 2019; Tofel-Grehl et al., 2017).

With early experience important to the development of interest in STEM fields, preparing teachers to engage students in STEM learning in ways that proactively engage their identities is of critical importance. However, rural teachers receive

less training and professional development (PD) opportunities than their urban counterparts (Howley & Howley, 2004; Oliver, 2007; Rude & Brewer, 2003; Weitzenkamp et al., 2003). Designing professional learning for rural teachers requires attentiveness to and understanding of their unique community needs. This paper explicates the iterative design of a teacher PD workshop and curriculum targeting rural teachers and students in an integrated set of computer science, science, and social studies projects that emphasize the salience of students' personal, community, and cultural identities in lessons that incorporate STEM concepts alongside the study of local history.

Background

The ongoing process of economic globalization impacts communities worldwide. With efforts to create a “free flow of capital, people, news and information via electronic media from one country to another” (Abdul Razak, 2011, as cited in Paziresh et al., 2013, p. 116), many smaller, less mobile communities are excluded from initiatives and processes intended to further international efforts toward globalization. Educational goals and content shift to reflect the larger national and international goals established for economic reasons, such as

America's push towards STEM dominance (e.g., the America Competes Act of 2007). The shifting national and international educational goals and standards often create mandates for communities without providing resources to address them.

According to the 2010 U.S. Census, 51 million residents claim the rural United States as their home, living in communities with varied geographies, demographics, and economic interests. Tieken (2014) observed, "Rural America covers Native American reservation communities in the West, small mostly white New England fishing villages, midwestern farm towns with growing Latino populations, African American communities scattered along the Mississippi Delta, and isolated hamlets tucked into the Appalachians and Rockies" (p. 6). And yet, ruralness is more than geography. Tieken (2014) suggests: "the *rural* in rural is not most significantly the boundary around it, but the meanings inherent in rural lives, wherever lived... it is not simply a matter of boundaries. It constitutes one's identity; it shapes one's perspectives and understandings; and it gives meaning to one's daily experiences" (p. 5). Teachers in rural spaces are often products of rural communities themselves as research indicates 80% of rural teachers are employed in schools within 13 miles of their hometown (Miller, 2012). This *de facto* "grow your own" relationship indicates that rural teachers' experiences have made them aware of the nuances and necessities associated with teaching in rural schools (Lavalley, 2018).

Prior to the industrial revolution, the United States largely embodied a rural identity. However, as industrialization redefined the U.S. experience, rural communities were completely transformed. Declining populations and economic instability have necessitated that rural schools do more with less. Furthermore, with school funding models focused on localized tax revenue to support local districts, rural spaces with typically lower taxes suffer from a weaker ability to raise funds to support education. As standardization and accountability measures increased in the latter half of the twentieth century, rural schools were expected to maintain adequate yearly progress alongside their urban and suburban counterparts despite decreased funding and access to necessary resources (Lavalley, 2018). Further,

the needs, experiences, and contexts associated with teaching and learning in rural communities have largely been ignored given the attention to urban and suburban schooling. Today, rural schools are responsible for the education of one fifth of students in the United States, yet reliable access to high-quality professional development remains challenging for most rural teachers.

Rural Schooling

Rural students, especially those of lower socioeconomic status, have far fewer opportunities than their urban and suburban peers to take school computer science (CS) courses (Google & Gallup, 2016) and have less access to technology both in and out of school (Croft & Moore, 2019). While 29% of all public-school graduates have taken courses in biology, chemistry, and physics, only 20% of rural high school graduates have done so (Kena et al., 2016). In addition to lacking CS opportunities and after school clubs (Google & Gallup, 2017), rural students lack fundamental Internet connectivity outside of school (Croft & Moore, 2019). This overall lack of access for rural students is exacerbated for non-white students (Babco, 2003; Google & Gallup, 2016; Horrigan & Duggan, 2015). Yet, in a survey disseminated by Google and Gallup, they found that only 34% of rural principals and 36% of small-town principals felt that computer science education should be integrated into other school subjects in spite of growing evidence that knowledge of computer science is needed for many rural jobs (Butrymowicz, 2012; Mader, 2014; McFarland, 2016). Given this landscape, it is imperative that we provide opportunities for rural teachers and students to engage in integrated STEM learning.

In contextualizing the rural student experience, understanding rural teacher experiences and opportunities becomes critical to supporting and facilitating rural educational change. Research on rural education demonstrates that teachers understand the necessity of adapting their practices to meet the needs of their rural students (Kelly, 1986; Miller-Lane et al., 2006). However, rural teachers typically have fewer PD opportunities due to barriers of physical distance, limited resources, and staff availability (Howley & Howley, 2004; Oliver, 2007; Rude & Brewer, 2003; Weitzenkamp

et al., 2003). In addition, they often rely on the income from second jobs to meet their financial obligations, meaning they are unable to take advantage of optional PD opportunities offered after school hours, on weekends, or during summers because they cannot afford the lost income or travel time (Tofel-Grehl & Searle, 2019).

Although relatively few studies focus specifically on the PD needs of rural teachers, those that have typically find that there is a severe lack of ongoing PD for integrating technology (Alexander et al., 2014; Jones-Kavalier & Flannigan, 2008; Nasah et al., 2010). Due to the remoteness and isolation of rural schools, it is often challenging to recruit and retain teachers from outside the local community. Additionally, teachers in rural schools are most likely to be underqualified and most likely to spend their entire teaching careers at their first district, possibly teaching multiple generations of students from their community (Cowen et al., 2012). It is however the changing demographics of rural communities that further the disconnect of teacher populations. Because rural communities have been historically white, it is unsurprising to find that 90% of rural teachers are white while roughly 30% of students are not and the non-white student population is the number one growth statistic within rural schools (National Center for Educational Statistics, 2010). These shifting demographics mean changes in the needs of the evolving community. Further, the more highly ruralized the school, the more robust these trends become. As such, hiring and firing strategies cannot be used effectively to sustain improvement of classroom instruction due to the small pool of prospective applicants (Barrett et al., 2015). Thus, in-service PD is a singular and essential tool for improving educational opportunities for low-income rural communities. This confluence of considerations demands focus on supportive and effective training for both rural and highly ruralized teachers.

Overview of the E-STITCH Project

The Elementary STEM Teaching Integrating Technology and Computing Holistically (E-STITCH) is a curriculum development project designed to facilitate meaningful scientific inquiry related to physical science with technology, including both

hardware and software applications and development, in grades 3-6. Project E-STITCH fully leverages the multi-subject nature of the elementary classroom to link STEM concepts with social studies and literacy content, providing a broader foundation of scientific engagement for students across a range of interests. Project E-STITCH draws upon the recent enthusiasm for the maker movement in education (Peppler & Bender, 2013), in which students engage directly with STEM content and skills through the design, prototyping, and creation of objects that are relevant to their interests and needs (Vossoughi & Bevan, 2014). Projects utilize paper circuits and electronic textiles (E-textiles) to design and build solutions to personally relevant problems. In contrast to conventional wires and breadboards, crafting circuit artifacts are created using novel materials such as copper tape, microprocessors, conductive fibers or conductive Velcro, sensors for light, sound, and pressure, and actuators such as LEDs and speakers. By crafting circuits using these materials to produce personally meaningful objects (e.g., t-shirts, backpacks), students engage in designing solutions that are intellectually rigorous as well as culturally and personally meaningful.

Project E-STITCH Curriculum

The E-STITCH project created a new set of computational circuit projects and curricular materials accessible to elementary students and their teachers to provide a series of integrated STEM technology lessons. In order to facilitate teacher use of the curriculum, we provided PD to improve content and pedagogical knowledge through the implementation of E-STITCH in the context of elementary STEM content standards with additional curriculum linkage to social studies. Continued PD is especially important in rural districts where teacher turnover is low and teachers' certification is often in a different content area than the subject they are teaching (Feldon et al., 2014). The E-STITCH curriculum leverages innovative technology experiences to provide a personally relevant context for learning foundational STEM concepts necessary for defining problems, developing and using models, analyzing and interpreting data, and designing solutions aligned with the Next Generation Science Standards

(NGSS) science and engineering practices and the elementary level Common Core Mathematics (CC-M) standards. The curriculum also addresses Utah Social Studies standards 5.1.1.a (Using Maps) and 5.4.3.a (Identifying Key Ideas, Events, and Leaders of the Civil War using Primary Sources). In addition to these specific content areas, we aligned lessons with literacy and mathematics standards. Table 1 articulates the integrated standards addressed by the E-STITCH curriculum.

Within the curriculum, students engage in three integrated STEM and Social studies projects. In the first project, students read texts showcasing stories of immigration, migration, and forced relocation. These stories are paired with science content learning around circuits and computer science, allowing students to design, construct, and code computational circuit timelines that retell the stories of immigration, migration, and forced relocation.

Table 1

Standards Alignment for the E-STITCH Project Curriculum

English/ Language Arts Common Core State Standards	SL 4.4 Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes. SL 4.5/5.5 Add/Include audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas.
Mathematics Common Core Practices	MP.1 Make sense of problems and persevere when solving them. MP.2 Reason abstractly and quantitatively. MP.3 Construct viable arguments and critique the reasoning of others.
Next Generation Science Standards	4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. NGSS-SEP Planning and carrying out investigations. NGSS-CC-5 Energy and Matter: Tracking energy flow into, out of, and within helps one understand their system's behavior.
Utah Science Standards	Sed-S-4.2.3 Plan and carry out an investigation to gather evidence from observations that energy can be transferred from place to place by sound, light, heat, and electrical currents. SedS-4.2.4 Design a device to convert energy from one form to another. SedS-5.2.2 Ask questions to plan and carry out investigations to identify substances based on patterns of their properties.
National Council of Social Studies Standards	NCSSI Describe ways in which language, stories, folktales, music, and artistic creations serve as expressions of culture and influence behavior of people living in a culture. NCSSIII Construct and use mental maps of locales, regions, and the world that demonstrate understanding. NCSSIV Identify and describe ways family groups and community influence individual's daily life and personal choices.
Utah Social Studies Standards	3.2 Students will understand cultural factors that shape a community. 5.1 Students will understand how the exploration and colonization of North America transformed human history.
Computer Science Standards	1B-AP-09 Create programs that use variables to store and modify data. 1B-AP-10 Create programs that include sequence, loops, and conditionals. 2-AP-11 Create clearly named variables that represent different data types and perform operations on their values.

For example, in Figure 1, we see a student programming a computational circuit they designed to share key moments in the book *A Place Where the Sunflowers Grow* by Amy Lee Tai, a story of the forced imprisonment of Japanese Americans during World War II.

In the second project, Freedom Quilt Squares, students engage in learning about and

recreating abolitionist quilts from the Civil War to examine the role of women, and particularly enslaved women, in subverting slavery. Abolitionist quilts contained secret messages and clues for enslaved people making their way north on the Underground Railroad. Using sewable circuitry and crafting tools, students sew quilts such as the one seen in Figure 2.

Figure 1

Student Computational Circuit Integrating Literacy and Social Studies

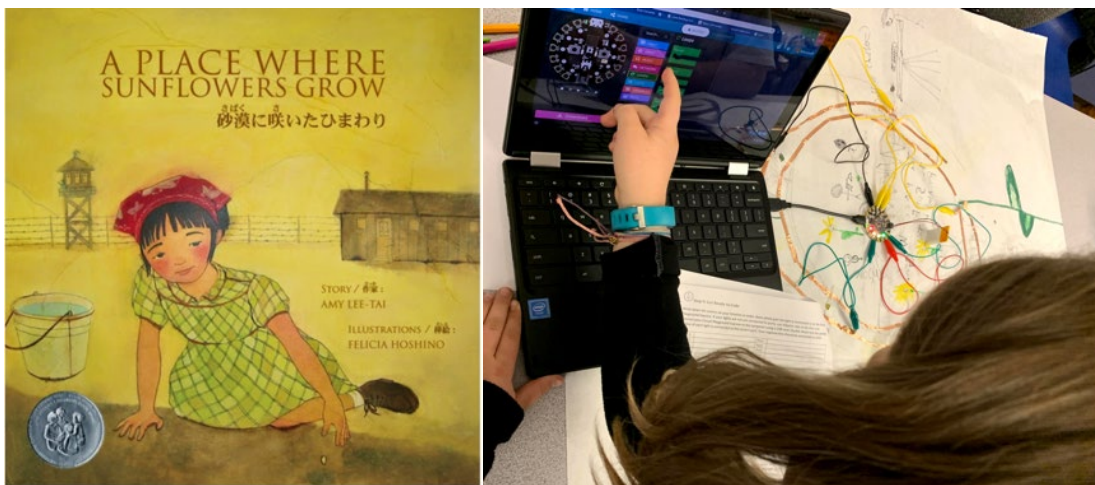


Figure 2

Student Freedom Quilt Squares

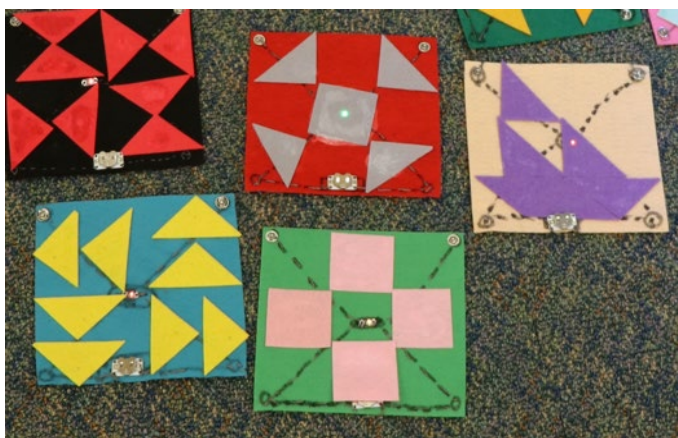
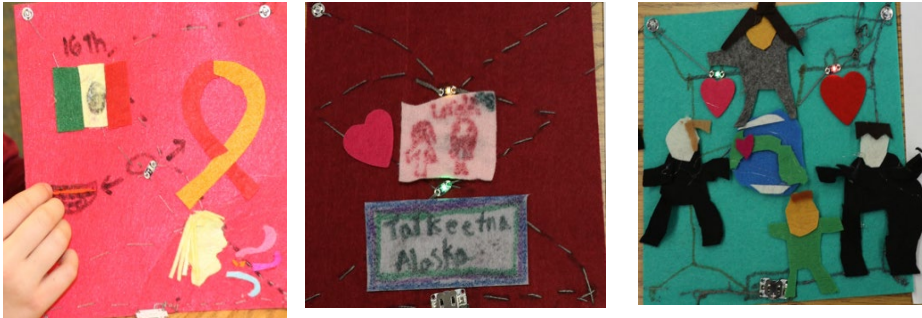


Figure 3*Meaningful Moment Squares*

In the final project of the curriculum, students are invited to share moments from their own personal history in the Meaningful Moments Project. Students are encouraged to reflect on their learning about human movement and, if they feel safe to do so, share a moment from their own family story of immigration, migration, or forced relocation. However, students are welcomed to share any moment in their lives or histories that they feel are meaningful and personal to them. Figure 3 shares some examples of students' Meaningful Moments Projects. Throughout each of these three projects STEM, and specifically science and computing, are used as tools in service to equitable teaching and rich social studies engagement. Doing this type of work within rural contexts takes specific strategies and awareness to meet the needs of teachers and students.

Research Questions

With the static nature of rural teacher employment and the lack of professional learning opportunities afforded rural teachers, a critical need arises for developing new strategies for supporting rural education, especially as rural demographics continue to shift. Integrating curricula within projects allows teachers more time and supports to begin to engage novel content while still engaging with the “known” so as to support their learning and manages cognitive load. Furthermore, given the need to incorporate more complete and inclusive histories within classrooms, providing rural teachers with a locally meaningful integrated STEM and social studies project functioned as a way to solve some of challenges faced by rural teacher

educators. With this opportunity to engage rural educators in improved professional learning, we posited the following research questions:

- 1) How can we design curriculum and professional learning for rural communities that allows them to integrate science and technology while also engaging narratives authentic to their rural spaces and students?
- 2) How do rural teachers experience teaching integrated learning on content specific to their students and community's history?

Theoretical Framework

Our approach to exploring the teaching of this integrated curriculum within rural and semi-rural classrooms was informed by critical whiteness studies (CWS). As such, we recognize that racism is a historic, endemic, and permanent feature of society (Gildersleeve et al., 2011; Ladson-Billings & Tate, 1995; Matias et al., 2014). Driving the persistence of racism is whiteness, an ever-shifting, hierarchical, dehumanizing ideology and power construct (Bonilla-Silva, 2010; Leonardo, 2009; Roediger, 1991). Whiteness informs every aspect of the lifeworld, from the personal, the educational, and the political.

As white people are the possessors and benefactors of whiteness, they are afforded racialized power and privileges in effort to further enshrine white supremacy within their lives. While white people and whiteness are not synonymous, white people are inextricably linked to this harmful ideology. Harris (1993) noted that whiteness operates as property for white people insofar that

the possession of whiteness grants them access to freedoms, flexibilities, and opportunities not available to people of color. As a result, white people are invested in whiteness because the retention of its supremacy affords them the ability to maintain the privilege and position of authority (Lipsitz, 1996). Importantly, because of the pervasiveness of whiteness, white people are often unaware of the depth to which whiteness influences their lives. According to King (1993), this dysconsciousness refers “not to the absence of consciousness, but an impaired consciousness or distorted way of thinking” about race/ism and whiteness (p. 135). Therefore, people embodying dysconscious racism are likely to accept, without hesitation, the lies, myths, and falsehoods used to protect whiteness.

Over time, these falsehoods become internalized as white common sense. Based on the Gramscian notion of common sense, white common sense insists that white ways of knowing and being are to be seen as normal or expected within white society (Leonardo, 2009). Conversely, information, perspectives, or suggestions put forth from beyond whiteness are situated as radical, impossible, or inappropriate. When white common sense is challenged, it can cause white people to evoke white emotionalities or emotional responses to encountering unplanned or undesired racial knowledge. Disgust, pity, defensiveness, guilt, and anger are emotions most commonly associated with white cognitive dissonance (Leonardo & Zembylas, 2013; Matias & Zembylas, 2016). Matias & Zembylas (2016) argued that within education, white emotionalities are also presented through performative evocations of love or sympathy (i.e., “I love all my students no matter what”; “I feel bad for what my students have to deal with at home”). In reality, these emotional responses function as a way for white people to assert their racist beliefs about a person of color through race-evasive signifiers deemed “appropriate” for teachers.

As Cabrera (2018) observed, whiteness is quite agile, not fragile, insofar that it mutates, evolves, and adjusts in response to attempted dismantling. Similarly, white people will do nearly anything to avoid having to account for their relationship to/with whiteness and white supremacy. Leonardo (2002)

articulated three ways that white people tend to embody whiteness. White people are often unwilling to articulate the ways that race/ism influences their experiences or how race/ism shapes complex social issues. Rather than name race/ism or whiteness, another less controversial identity construct will be identified as relevant (i.e., “This isn’t about race; it’s about class”). Second, white people will insist that racial identity has nothing to do with their experiences or the experiences of others. Rooted in race-evasiveness, white embodiment insists that because race does not matter to white people, it should not matter to anyone. Third, white people will seek to minimize the historical and contemporary presence of racism and white supremacy. This occurs in many ways, but notably through disassociating white people from racialized violence, whitewashing historical realities, and dehumanizing people of color while bowdlerizing white icons.

Within this contextual understanding of how simultaneously subtle and pervasive the dominance of whiteness is within social constructs, we explore the ways that an integrated STEM and social studies curriculum can facilitate rural teacher reflection and professional development in their teaching and relationships with their students.

Methods

To answer these research questions, we utilized design-based research (DBR) methods. The aim of DBR is to study learning and teaching while also generating theories and solutions. This framework allows researchers to observe, as well as intervene, throughout the study process. It involves engineering learning environments, systematically studying what takes place, and making adjustments (Cobb et al., 2003; Collins et al., 2004; Kelly, 2003). The objective of DBR is to develop a better understanding of the learning ecology, including interactions among teachers, students, content, and curriculum and how these relations affect teaching and learning (Gravemeijer & Cobb, 2006). DBR’s iterative design approach begins with development of the research problem before designing artifacts and/or curriculum to test a solution for the established problem. The curricula design is tested and then revised and

reimplemented (see Figure 4). Results from DBR studies produce solutions as well as newly developed problems to examine in subsequent studies. This study is at the fourth stage where effects from revised curricula are being examined.

Context

Rural populations represent an important sector for increasing STEM engagement. Leaks in the STEM education pipeline, combined with growing demand for a STEM-prepared workforce, reinforces the need to attend to STEM education in rural communities where qualified and skilled STEM workers are in especially short supply and limit the development of industry (Butrymowicz, 2012; Carnevale et al., 2011; Mader, 2014; McFarland, 2016). As such, it is crucial for educators and researchers to engage more K-12 students from all

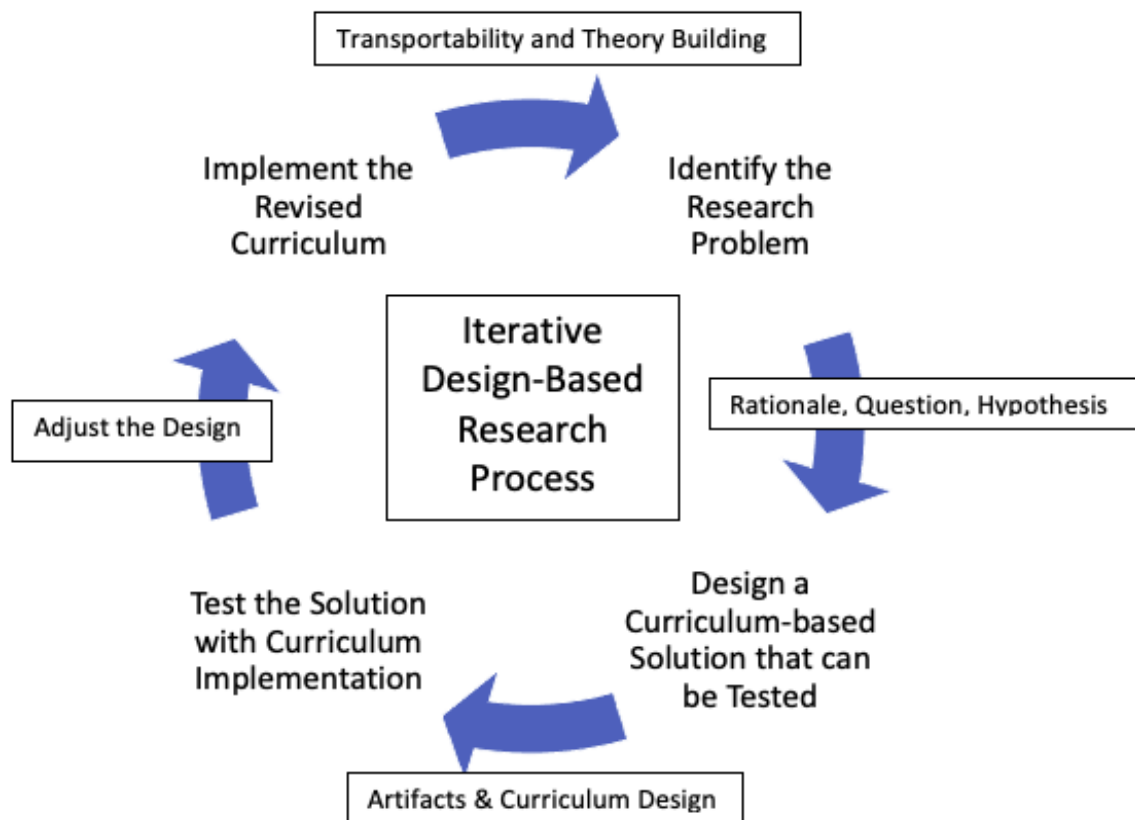
demographic groups in STEM learning and help them to sustain their interests in STEM-related fields.

Definitions of rural communities vary. We engage the definitions of highly rural and rural spaces in the way outlined by the Veteran's Administration

(<https://www.ruralhealth.va.gov/aboutus/ruralvets.asp#top>). These definitions articulate highly rural spaces as a "sparsely populated areas [with] less than 10 percent of the working population commuting to any community larger than an urbanized cluster, which is typically a town of no more than 2,500 people." Conversely, they define an urban area as one where 30% or more of the population live in a densely populated area as defined by the Census Bureau. However, between

Figure 4

The Iterative Design-Based Research Process



Note. We adapted this Iterative Design-Based Research Process from Middleton et al. (2008).

these two spaces, the Veteran's administration also recognizes the "semi" rural, spaces that are neither urban nor highly ruralized. This intermediate definition and nuanced understanding about the variance within and across rural communities affords our work more clarity for understanding the communities with which we work in the state of Utah. Table 2 provides details regarding the rural communities in this study.

Description of the Professional Development

The PD workshop was developed using design-based research methods with a specific focus on the needs of rural teachers. Intended as an iterative and ongoing process, the PD provided teachers with a weeklong workshop and followed up with support team meetings and review as necessary.

The first phase of PD was the weeklong summer institute delivered in or proximal to each participating school district. This workshop sought to achieve two specific goals. First, we needed to ensure that teachers possess or develop appropriate content knowledge and inquiry-focused pedagogical knowledge. Because of the deficit of qualified science teachers in Utah (Feldon et al., 2014), ensuring proper content knowledge for teachers was vital to effective classroom instruction for students (Forbes & Davis, 2010; Windschitl, 2004). Using the 5E instructional model (Bybee et al., 2006), we modeled effective inquiry pedagogy

during the institute and ensured participating teachers could explicate and map the target projects onto the engagement-exploration-explanation-elaboration-evaluation sequence to facilitate student participation. Second, we trained teachers on the E-textiles projects, including basic Arduino coding skills, such as working with variables, constructing conditional statements, looping, and using functions, so they were comfortable teaching the projects in their classrooms and linking them to the relevant science content standards for their state and grade level.

In teaching teachers who have never read code how to comprehend and teach the content, we found a faded scaffolding approach to be most effective so as to emphasize the importance of tracing, commenting, and explaining code as a means for developing understanding (Lopez et al., 2008; Murphy et al., 2012; Teague & Lister, 2014). We used a three-stage faded scaffold to introduce teachers to the reading and commenting of code. In the first stage, teachers received a piece of code for a basic blink program, which turns an LED on and off, with the entirety of the comments included. The PD leaders read and discuss the code, explicating what each line does and what the comments tell us about the code. Teachers then attempted to use the basic blink code with their completed projects and modified it to make the lights blink in different sequences or frequencies.

Table 2

Participant Demographics

	^a Abzug County	Hayduke County	Utah overall
2017% rural population	16.0%	78.0%	23.8%
Percentage white	84.0%	45.8%	89.0%
Population density persons/mi (state rank)	96.7	1.9	34.0
Total # and % of rural preK-12 students	35,599 (31.6%)	5,015 (34%)	551,013 (15%)
% of students qualifying for free/reduced lunch	42%	70%	37%

Note: District and location names are pseudonyms.

^aSarvis City is located within Abzug though Sarvis City Schools are independent of Abzug County Schools.

In the second stage, teachers received the entire code and comments for the set-up section of the code. They then commented the lines of code that did not have comments. Answers and comments were checked for correctness and accuracy.

In the third stage of the training, teachers received a section of code and were asked to comment every line. Teacher ability and comprehension were checked a final time before teachers began learning the next process—writing code for themselves.

After the workshop, the second phase of the PD involved site visits per school to meet with teachers and review E-textile projects prior to and following classroom instruction as needed. These meetings allowed teachers the opportunity to review the content and projects, gain assistance in troubleshooting and planning, and engage in structured reflection after deploying their units. The frequency and duration of site visits varied so that teachers who required higher levels of support received it. Due to the COVID-19 pandemic, the training moved from a face-to-face workshop to an online workshop.

Positionality Statement

The research team for this project consists of four white faculty members and one Latinx faculty member at a land grant institution in Utah. Four of the five faculty members have taught in schools; the fourth scholar is a learning scientist with extensive teaching experience in informal learning environments and expertise in working with Indigenous populations. As scholars, we each hold different theoretical frames and areas of interest. Of importance, many of the scholars on this research team grew up in urban spaces, but all have spent between three to eight years living in a semi-rural community. Our university affiliation as faculty within the state's only land grant institution and teacher educators within that community carries with it heightened access to working with rural teachers across our state.

Participants

In the first year of the E-STITCH program, 19 teachers participated in the PD workshop; all the

teachers came from highly rural or semi-rural communities. In year two, 23 teachers completed the entire online PD. Of those, 12 of the teachers came from highly rural and semi-rural spaces. Another 11 teachers came from an urbanized school district interested in the curriculum and professional learning opportunity. Three of the teachers were male while the rest were female. Some of the teachers were foreign nationals who were teaching in Utah. One teacher was Navajo.

Data Collection

For analysis within this study, we collected professional development documents and assignments, teacher interviews pre- and post-professional development, and classroom observations. Observations occurred over the course of instruction that typically spanned 3 weeks for a total of 15 classes.

DBR Process

In the beginning stage of our DBR process, the articulation of the research challenge, we noted that both semi-rural and highly rural teachers experienced little to no professional learning opportunities for teaching science, social studies, or computer science. Within Utah, we could find no professional learning opportunities at all for elementary teachers related to social studies; similarly, the opportunities for science and computing were notably slim for rural educators. With this defined problem, and cognizant of the limited teaching time available to teachers for untested content areas in a state with extensive high stakes accountability testing, we engaged in PD design intended to integrate technology, social studies, and science curriculum pedagogy for elementary teachers in our second stage of DBR. We centered around three craft-based projects that would allow teachers to engage students in learning across the upper elementary social studies content for fourth and fifth grades incorporating STEM knowledge and skills.

Analysis

We report our findings in two parts. Firstly, to address our first research question that sought to understand how we design curriculum and PD for rural spaces, we share reflections and observations

on the development and implementation of professional development in STEM. This analysis explores the reflections of the program providers as well as program development documents and teacher feedback.

Secondly, in order to understand how rural teachers experience integrated content learning within their communities, we coded common themes across teacher participants; transcripts of teacher interviews as well as assignments and reflections from professional learning were independently open-coded by two researchers using emergent thematic coding (Saldana, 2013). This coding allowed us to explore both the expected and unexpected experiences of teachers as they integrated STEM with social studies. The researchers then resolved coding disagreements by consensus. After the initial coding, the team consolidated codes with a focus on challenges and experiences that could inform future iterations of rural teacher professional development. This focus provided an understanding of both the unique rural space the teachers worked within and the iterative DBR process. We report on two of those themes here: (1) racial differences in teacher experiences and (2) common experiences across teachers.

Findings

Designing Professional Learning for Rural Teachers

Initially, we found there to be a lack of professional learning opportunities for elementary rural teachers in both social studies and STEM areas. This determination arose from a search of the state's professional development offerings and discussions with school districts' stakeholders. The first iteration of the professional development and curriculum scaffolded teacher engagement with the technology and construction of novel maker projects. Initial analysis of the data from the professional development workshop and classroom deployments indicated that teachers were struggling to have hard conversations with their students regarding uncomfortable histories. As one teacher noted, they were concerned that discussions of slavery would make students sad or that they would be too emotional for young people. In reflecting on how difficult the teachers, and most

notably white teachers, felt these conversations would be, we decided to use the opportunity presented by the COVID 19 pandemic, which forced our professional development work online, to provide teachers more scaffolded and, hopefully, more reflective opportunities to engage with the ways in which their own race impacted their experiences, their teaching, and their comfort in having these hard conversations.

Simultaneously, we found evidence of teachers struggling to integrate technology to teach coding for the first time. In support of that finding, we engaged a similar process of scaffolding and commenting code to support teachers in their development. We presented science and computing knowledge as tools for facilitating learning about complex histories so as to centralize the difficult conversations teachers articulated hesitancy in having. The design of the curriculum and professional learning centered perspectives often ignored in the state's social studies lessons. For example, much of Utah's fourth grade social studies curriculum focuses on the Mormon Migration. However, few, if any, teachers grapple with or acknowledge the forced removal of Indigenous peoples from their lands as part of that process.

Understanding that rural teachers across Utah would be working with Indigenous students and communities, we felt that centralizing these stories was an essential part of their professional development as educators. By centralizing these stories and histories of rural Utahns within a larger unit, our effort sought to provide a personally relevant and meaningful learning opportunity for teachers and students through which to build connections. Within this curriculum, science and technology served to support the telling and exploring of these stories of human movement by facilitating the construction of new ways to express these forms of human movement. This dual challenge to teachers allowed them to move back and forth between challenge areas. While it might seem counterintuitive to provide scaffolds to these two divergent challenges simultaneously, doing so allowed teachers to manage their feelings and angst about both, shifting focus and engagement between them as needed. By managing their cognitive load in both areas through scaffolding, we observed that

teachers demonstrated greater flexibility and engagement.

In the final stage of our DBR process, we reflected on the outcomes, opportunities, and limitations of our first iteration. In this analysis, we recognized that rural teachers required greater PD and support to engage students in difficult conversations around uncomfortable aspects of history as well as increased scaffolding for technology use. Teacher reflections indicated that their own identities played some role in their teaching of these stories, particularly in rural spaces wherein these histories were deeply personal and important. Table 3 outlines the DBR process and prior findings that led to the recent changes and accommodations for rural teachers.

Our second iteration of the PD was online as a result of the COVID-19 pandemic. While this change was not anticipated, we leveraged the opportunity to engage teachers in private reflection about the ways that their personal identities impact their teaching practices. We increased scaffolds, materials, and opportunities for teachers to think about and engage with their own personal identities with regard to their professional actions. Because of a lack of prior knowledge and experience teaching both the full localized histories and technologies, we recognized the heightened need for rural teacher professional learning to be both contextualized and highly scaffolded to prevent cognitive overload.

Teachers' Experiences

Across the multiple deployments of the program, themes emerged related to teacher experiences of the curriculum and PD opportunities. Teachers' own racial identities as well as those of their students shaped their experiences of the professional learning. However, while some experiences were unique to individuals, others were more common to all regardless of ethnicity or geographic location.

Across STEM education, subject matter is typically framed as divorced from issues of identity and culture (Heybach & Pickup, 2017; Vradi & Dayal, 2016). However, this narrative is historically inaccurate (Faulkner, 2000, 2009; Nasir & Vakil, 2017) and promotes a narrative that STEM belongs

to those with white and masculine identities who have historically populated it (Carlone & Johnson, 2007). This narrative leads to identity dissociation with STEM and constrains students' views of who can legitimately engage in STEM (Archer et al., 2010; Calabrese Barton & Tan, 2019). Accordingly, it is essential that students have opportunities to see their own identities as not only compatible, but integral, to STEM engagement. The E-STITCH curriculum intentionally positions students' identities in this way by linking their cultural, familial, and personal narratives of immigration, migration, and forced relocation with deeply integrated STEM learning. Specifically, the E-STITCH curriculum utilized Bishop's (1990) attention to the use of curriculum resources that serve as windows and mirrors. Through this frame, the E-STITCH curriculum engaged students in materials focused on immigration, migration, and forced relocation that reflected the experiences of students who have experienced them (mirrors) while also offering students lacking personal connection to these issues an opportunity to gain insight on the lived experiences of others (windows). Thus, teachers' abilities to both support and center the cultural and personal identities of their students within classroom discourse is vital to successful teaching, particularly for curriculum that calls for personally meaningful learning as a foundation for sustained engagement in STEM opportunities and pathways.

Racialized Experiences of Curriculum

Teachers who participated in E-STITCH PD and then implemented the curriculum in their classrooms had differing experiences depending on their own racial and ethnic backgrounds. Most white rural and semi-rural teachers who participated had not typically spent a lot of time thinking about their own identities, especially how their racial identities shaped their worldviews and how they interacted with their students who were non-white. This may be due to white population making up an even larger percentage of the rural American demographic (78%) compared to the rest of the country (64%; National Center for Educational Statistics, 2010).

Table 3*Summary of Design-Based Research Reflection Process*

Initial Problem	Iteration 1 Solution	Findings from Iteration 1	Iteration 2 Changes
Rural teachers lack PD in STEM and Social Studies.	Develop integrated STEM and Social Studies PD and curriculum.	Teachers struggle with hard conversations with students and need more training.	Online PD scaffolds increased reflection on identity and hard conversations.
Rural teachers struggle to integrate technology.	Integrate computing into STEM and Social Studies projects meaningfully.	Teachers need more scaffolding for computing.	Scaffold project structure to support teacher integration and adoption.

Note. PD = Professional Development; STEM = Science, Technology, Engineering, and Mathematics

Many teacher participants were uncomfortable with merely being asked to reflect on their own identities. As one white teacher responded when asked to reflect on the identities that were most salient to her as a teacher, “I don’t understand the question” (Interview, August 2, 2019). Another teacher, when asked how teaching the E-STITCH curriculum caused her to reflect on her own racial and ethnic identities, responded, “Um . . . I didn’t just because, I don’t know, it’s not super important to me” (Interview, February 5, 2021). However, she went on to stress the value of E-STITCH for her students, “especially those who came from rougher backgrounds” because it allowed them to connect with their parents.

In both responses, we see evidence of the troubling assumption that white people do not have racial and ethnic identities and that these identities do not shape their interactions with students or their interactions with science curriculum. As Matias & Zembylas note, these evocations of affection are juxtaposed with an othering and distancing from their students’ racial identities. This is made more explicit by the second teacher who implied that her “students from rougher backgrounds,”—a euphemism for her students of color—can benefit from reflecting on their identities.

In contrast, teachers of color, the majority of whom were international teachers living in the

United States temporarily to teach in dual-language immersion programs, saw themselves in the experiences of immigration, migration, and forced relocation represented at the heart of the project E-STITCH curriculum. As one teacher reflected, “When I was telling them (the students) about migration and immigration, I was telling that, ‘You know, you know a person that comes from another place. Me.’” For other dual-language teachers, the sentiment of having lived the experiences talked about in the E-STITCH curriculum was less pleasant. One Chinese teacher, for instance, described how rural white Americans treated her when the COVID-19 pandemic hit:

So, like, I was attacked because I was, I was some of the first ones who wear a face mask once it started. And like . . . it’s like, we have poor air. It’s not speaking ill of my country. Because we have more, much more pollution than here because of the large population [of] factories. So we, we, are used to wearing a face mask, when it was dry or when the air is not good. It’s not because we are sick. So I even have some [masks] before, uh, at first at the face masks were, were hard to buy, but I happen to have some, because it’s just my habit to wear those when I have nose allergy or in the air, it’s not good. And they think like, I’m the sick and I, that caused a big problem because I’m Chinese” (Interview, September 21, 2020).

Unfortunately, for this teacher, it was the anti-Asian sentiment experienced by herself and other Chinese teachers that connected her to American history, perhaps especially the experience of Japanese internment during World War II depicted in the picture book, *A Place Where Sunflowers Grow* by Amy LeE-Tai and Felicia Hoshino. *A Place Where Sunflowers Grow* is included in the E-STITCH curriculum specifically because it shares the story of one family's internment in Utah during WWII. Those experiences also directly connect issues of identity and ethnicity to current STEM issues related to health and efforts taken to limit the spread of COVID-19. Through these quotes, we see how teachers from different racial and ethnic backgrounds thought about their own identities in relation to the E-STITCH curriculum.

Common Discomforts with the Curriculum

Regardless of racial or ethnic background, teachers were nervous about having hard conversations with their students about systemic and historic inequity in the United States. For white teachers, there were more frequent concerns about whether students would engage in conversations about difficult topics respectfully as well as a desire to avoid hard conversations. For instance, in reflecting on a "proud teacher" moment where her students engaged in respectful dialogue, Ms. Natuna sheds light on her fear that this was not how things would play out in the classroom. She recalled:

One of my [students] is Navajo, and we were talking about the French and Indian War, and she was kind of a little bit upset that the textbook said Indian. One of my other kids was kind of talking to her about how, well, this is how they talked back in the time period and it's okay that we talk about or used the words that they – I mean within reason obviously – but he said we use these words because they're time appropriate and we need to understand where they're coming from versus where we come from, it just kind of helps get a better historical perspective, which she thought was kind of cool and I was super proud as a teacher. I was like, "Oh! Amazing," but I think she learned we weren't trying to be offensive with it, it was just

the text and just kind of helping her know that we respect and understand, maybe not fully understand, her culture, her perspective, but just we value her as part of our community, and we want to make sure she feels comfortable.

This anecdote of "proud teaching" requires closer examination. We see Ms. Natuna surprised at the dialogue between a Navajo student and a white student. She classifies this conversation as respectful and that "we weren't trying to be offensive with" the use of the word Indian. In this exchange, the Navajo student's emotions are set aside in place of attention to the presumed historical accuracy of the terms being used. The white student is positioned as an expert and the Navajo student is expected to not feel upset. In this way, Ms. Natuna and the white student are positioned as being unilaterally able to determine if something is offensive, racist, or inappropriate. While Ms. Natuna and the white student believe they are "helping her" understand the truth about historical representations, in reality they are silencing the Navajo student, indicating that her feelings are invalid or that her understanding of the past is inaccurate. The only people remaining comfortable through this exchange are the white teacher and student.

White teachers also struggled with how to talk about something so explicitly value-laden in their classrooms, even while recognizing that it was unavoidable. As Ms. Angling reflected:

Oh, like the lessons on how to talk about hard conversations [were] I think really important because we're gonna have some really hard conversations going back to school. Yeah, for sure. It's with everything that's going on in our world. And it's great. In fifth grade, we talk a lot about slavery and things like that. So, it was just a nice refresher to talk about, like to have that in this discussion this year. Mm hmm. Um, yeah, I do think as teachers, we have a very, we have to walk a very fine line, because we need to give students the facts. And we give them an outlet to talk. But we also cannot put our impressions on students.

Ms. Angling's use of the term "the facts" makes it clear that she does not want to engage in a conversation about values or (in)equity with her students. Many white teachers felt similarly that it was not their job to opine on whether something like slavery was right or wrong. In reality, though, their framing of just "the facts" implies that the existing social studies curriculum is value-free. As with science, we realize that social studies curricula are value-laden and often results in educative-psyche violence for students with marginalized identities (King & Woodson, 2017). Moreover, Chandler and Branscombe (2015) suggest that white social studies propagate white perceptions of the past, is filled with white heroification, and minimizes the experiences and perspectives of people of color. Therefore, claims of teaching just "the facts" often refer to the white facts.

However, there were some exceptions wherein teachers recognized the importance of teaching social studies from a culturally responsive perspective as the E-STITCH curriculum suggests. Ms. Fasua taught at a rural school with many students who had recently immigrated to the United States, and she commented:

So for, for my students, I'm going to be bringing in the literature and talking a lot about, um, because they, they are in a situation where many of their families are immigrants or have migrated currently, not even a long time ago, but they are currently possibly in flux. And so I think, um, I think my goal is to get them, to get the students, to see that, you know, that's kind of how America was built. Um, and that, that all of the cultures that have come have helped make this such a beautiful, wonderful place, right. Their cultures and what they're bringing are important to our history and our future (Post-PD Interview).

In this reflection, Ms. Fasua sees her students' experiences reflected in the E-STITCH curriculum, and she articulates how she hopes to use the lessons of project E-STITCH to make her students feel welcome in the United States even when their lives are in flux. Ms. Fasua's framing of the United States' past is such that students see the central role that immigrants have played, rather than

situating immigration stories as external to the traditional narratives that fill social studies curricula (e.g., Journell, 2009). Similarly, after having taught E-STITCH, Mr. Smith reflected on the experiences of a Somali student in his class. He said:

I have a child in my class who's from Somalia, and it was like this content is specifically meant for accepting people like her. We're talking about how everyone came from all these different places and how we have different traditions and different ways of dressing and different things that we eat. I thought that was really powerful for her. I wish she would have been a little bit more outspoken about it. Because she would talk to me away from the class and say this is the exact same thing that I'm feeling. But she would never share it in front of the class. And I was hoping she would" (Interview, November 12, 2019).

This reflection from Mr. Smith offers a glimpse into the ways that teachers can simultaneously make progress toward more equitable teaching and also provide evidence that more support is needed. While we see hints of Mr. Smith's own problematic stance towards multiculturalism in his emphasis on traditions, clothing, and food, it is also worth noting that he recognized the value of the curriculum for his students. Mr. Smith is able to identify the value of integrating texts and resources that centralize experiences of students too often ignored in social studies curriculum. That said, the disappointment he shared when his Somali student would not vocalize her appreciation for the cultural content featured in the E-STITCH curriculum indicates that Mr. Smith placed the responsibility of vocalizing meaning upon the shoulders of the immigrant student in his class.

At the same time, though, Mr. Smith could not articulate the value of learning about the topics covered in E-STITCH for his white students. Thus, he indicated a lack of awareness that diverse texts serve the role as mirrors and as windows, both of which are necessary in elementary classrooms (Bishop, 1990). Students whose identities are centralized in the traditional curriculum (white, male, United States born) often have no issue seeing versions of themselves reflected in the curriculum.

Teaching about immigration, with sources from people directly experiencing immigration, can assist white U.S.-born students in developing a humanizing understanding of the nuances, challenges, and opportunities associated with immigration. Specifically, in rural contexts, Mr. Smith could have utilized the E-STITCH curriculum to deliberately transform students' understanding of these complex issues, illuminating the realities of immigration, migration, and forced relocation for rural students and offering them a window into how others have experienced these events. Instead, however, Mr. Smith focused discussion on the lighthearted cultural representations referenced above in hopes that appreciation of others' traditions would suffice.

Dual-language immersion teachers had other concerns about having hard conversations, specifically that they had recently arrived in the United States themselves and did not fully understand the history or the social systems they were being asked to teach about. One Portuguese immersion teacher reflected on how nervous she was about teaching the social studies portion of E-STITCH before she started teaching:

Also, the social studies part 'cause I don't do that here, and well, I'm not from here. I'm from Brazil, so I'm not so sure how kids will receive the things I was telling them. 'Cause I know how it works in Brazil; how everybody thinks and how the politics work. How can I say that? The social part. The culture, yeah. I didn't know how they would receive what I was teaching, but it was really good. They were capable of thinking critically about that. They were able to understand everything, and to participate, and understand the topics that we were talking about (Post-Instruction Interview).

While this teacher was ultimately surprised by her students' abilities to engage in hard conversations about immigration, migration and forced relocation, she continued to be uncertain about how her students would react to things she might say about, for instance, politics in the United States as someone who had grown up in another country and had only been in the United States for several years. Similarly, Ms. Winn described how

the topics of immigration, migration, and forced relocation were new to her. She articulated:

This is completely new for me. Like I am a Chinese immersion teacher and this, I just finished my second-year teaching here. So, for what I learned and experienced . . . here, this curriculum is new...I think teachers don't usually talk about that big topic with students, especially at an elementary level, like for social studies. I'm interested in the American history, like especially Utah history. I learned that when they, uh, when teachers teach social studies, they only mention like how pioneers ... work hard to make a life here in Utah. But, they don't talk about how they deal with the conflicts or maybe not conflicts with the Native Americans. So, I asked a few people and they tried to find a nice way to say that. And I found some teachers are not willing to talk about that....So, this is impressive. Um, I never thought I would talk with elementary kids, uh, like about this big topic, especially about the, uh, social equality (Post-Instruction Interview).

Although the social studies topics featured in the E-STITCH curriculum were new to Ms. Winn as they were grounded in U.S.-centric perspectives, she acknowledged the ways that traditional social studies teaching falls short of engaging students in rich discussions of complex issues. Particularly in the context of Utah, stories of immigration, migration, and forced relocation are viewed through the pioneer perspective, shielding greatly the impact that historical and contemporary figures have on others, on the land, and on communities. As a Chinese national teaching in a dual-language immersion program in a rural part of Utah, Ms. Winn was able to see the omissions in social studies curriculum, such as only teaching about "how pioneers . . . work hard." For her, the E-STITCH curriculum presented an opportunity to engage not only her students but also her U.S.-born white colleagues in talking about systemic inequities. She became very attuned to the silences and omissions of U.S.-born white teachers.

Discussion

Rural teachers are a unique population of teachers, specifically because they tend to stay in their communities, work more years within their localized schools than their urban counterparts, and receive fewer opportunities for professional learning. Further, these communities often struggle most to sustain STEM-based workforce pathways (Rothwell, 2013) and are currently seeing the greatest diversification of their populations (Lichter, 2012; Lichter et al., 2018). Accordingly, many rural communities are struggling with ethnodemographic and cultural changes that local schools are ill-prepared to address (Lichter et al., 2007). It is essential for rural communities to provide professional development for their teachers. In addition, teachers need the pedagogical resources to engage with the complex U.S. histories centralized around the communities they serve.

Whiteness had a direct impact on how teachers engaged with E-STITCH. Despite efforts to disrupt whiteness by centering literature written by/about people of color and providing professional development on racially literate teaching, white teacher-participants still struggled to disrupt whiteness within their daily practice with students. For white teacher-participants, whiteness manifested through a protection of white emotionalities (Matias & Zembylas, 2016) and a dysconsciousness when considering the ways that students of color experience the world. Additionally, white teacher-participants struggled to account for the experiences of their students of color who had cultural or historical connections with the events that were addressed in E-STITCH. This suggests that participants were unable to transfer their newly developed racial pedagogical content knowledge into racially just racial pedagogical decisionmaking (Hawkman, 2019).

As Leonardo (2009) observed, whiteness dehumanizes people of color, reducing their experiences to be secondary to those of white students. At times, however, E-STITCH offered teacher-participants of color an opportunity to acknowledge their own experiences with immigration, migration, and forced relocation, thus serving to humanize these experiences in the eyes

of students, many of whom had few encounters with such actions. In addition, E-STITCH reflected the stories of students of color who had experienced immigration, migration, or forced relocation in their young lives, thereby pushing back on ways in which whiteness ignores the experiences of people of color within traditional curriculum.

Within our study, STEM serves as a tool for facilitating an opportunity for deeper conversations and reflection within rural classroom communities. Early exposure to positive STEM experiences, a likely predictor of future STEM interest, engages learners in integrated STEM learning that is personally relevant and contextualized may provide an essential link to improving STEM learning outcomes for rural communities. The E-STITCH curriculum and its associated PD offers students and teachers the opportunity to develop projects that localize community histories and broach personal experiences while utilizing STEM knowledge and practices in the telling of those histories. While STEM learning is important for its own sake, opportunities to integrate STEM across contexts are important because they afford students more opportunities to see classroom learning as relevant to themselves and their lives. However, to do this, students need teachers with the ability to engage STEM dynamically across the curriculum.

Conclusions

There exists the illusion that STEM knowledge and, by extension, STEM learning is devoid of politics, opinions, and contexts. By framing STEM this way, educators and STEM participants erase the stories, considerations, needs, and contributions of entire swaths of the population. In doing so, we have created two specific challenges for STEM educators. Firstly, we reinforce the notion that there is one way of engaging STEM. Secondly, we support the perception of some people as STEM people and some people as not. Typically, this means that STEM remains the bastion of white men. Creating alternative narratives around who can do STEM and what STEM looks like requires early interventions that are equitable and accessible for all students.

To create equitable opportunities for students, professional learning must be equally accessible.

With rural communities retaining their teachers in service longer than their urban counterparts, professional development and learning provide significantly valuable opportunities for continued improvement of STEM learning and interest among rural students. The E-STITCH program engaged rural teachers in professional learning and training to support their acquisition of new skills, both in terms of STEM teaching and in terms of engaging their students in learning and thinking critically about the histories and issues in their world.

By engaging teachers in the same reflective processes their students were expected to engage in, teachers became aware of their own cultural worldviews. Their awareness of their perspectives was constrained at times as they were grappling with cultural and epistemic shifts around STEM teaching and learning. At first, participating teachers viewed STEM as a discipline devoid of cultural values before considering cultural worldviews of STEM. When teachers succeeded in bridging social studies and STEM, they often did so because their worldviews were often called into question. By examining the ways in which STEM can foster engagement with the histories and experiences that rural communities face in their daily lives, STEM becomes an important tool for empowering both teachers and communities.

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