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Culturally Responsive Storytelling Across Content Areas Using American Indian Ledger Art and Physical Computing

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Abstract

In July 2021, Computer Science (CS) standards were officially added as a subject area within the K-12 Montana content standards. However, due to a lack of professional development and pre-service preparation in CS, schools and teachers in Montana are underprepared to implement these standards. Montana is also a unique state, since American Indian education is mandated by the state constitution in what is known as the Indian Education for All Act. We are developing elementary and middle school units and teacher training materials that simultaneously address CS, Indian Education, and other Montana content standards. In this paper, we present a unit for fourth through sixth grades using a participatory design approach. Through physical computing, students create a visual narrative of their own stories inspired by ledger art, an American Indian art medium for recording lived experiences. We discuss the affordances and challenges of an integrated approach to CS teaching and learning in elementary and middle schools in Montana.

1 Introduction

The recent development of Montana's computer science (CS) standards introduces a state-wide momentum to expand computer science education to all students across the state. However, not every school has a teacher who specializes in CS, and many schools do not offer CS courses. As such, embedding CS into other content areas is essential for all students to experience CS content. At the same time, through the Indian Education For All (IEFA) Act enacted in 1999 (and enforcing a 1972 article of the state constitution), all students in Montana are mandated to learn about the most important issues impacting Montana tribes as well as local history, encapsulated in seven Essential Understandings (EUs) of the Montana Indian [5]. To integrate IEFA across the curriculum and across all grade levels, however, requires "a multi-pronged, comprehensive endeavor," which has been led by Montana's Office of Public Instruction (OPI) [8, p.38].

While there is no single American Indian epistemology, Brayboy [6] roots TribalCrit within the commonalities of American Indian communities across time, space, place, Tribal nation, and individual. In an effort to redefine what it means to compute and who computes, we leverage Brayboy's tenets of TribalCrit to ground introductory computing within the stories of American Indian People. Telling the stories of American Indian People, particularly individuals from Montana, educates students on American Indian concepts of culture and knowledge, while also recognizing students' own enculteration in Western culture. We encourage students to reflect on their sociocultural practices, to juxtapose those with stories from local American Indian communities, and to personalize and construct related computational artifacts.

In this paper, we describe an iterative curricular design process in which we partner with Montana teachers, OPI, and other stakeholders to develop culturally responsive resources for teaching the new CS content area that are also in line with IEFA. We present a sample unit for grades four through six, centered on ledger art that combine CS content standards, IEFA EUs, and other content standards (including Science, Language Arts, and Visual Arts). This paper gives a brief overview of the unit, along with the development process. We purposefully leverage electronic textiles (e-textiles) as a mechanism for physical computing in order to disrupt perceptions of traditional norms in STEM fields by combining traditionally Westernized and masculine activities like engineering and computing [7] with traditionally feminine and American Indian activities such as crafting [14, 17, 18]. We strive to develop students' interest in and identity within computing by engaging learners in non-traditional computing practices such as creative design, personal expression, and community engagement [13, 14, 19].

2 Iterative Curricular Design Process

In this section, we discuss the iterative development process, including team input, feedback from our research practice partnership (RPP) with Montana teachers and other stakeholders, including recommendations from an advisory board comprised of experts in computer science education and Indian Education. This RPP—following strategies outlined in [9]—is a partnership between researchers on the development team, the researchers and stakeholders in the advisory board (AB), and practitioners in the master teacher panel (MTP).

2.1 Research and Development Team

The ninth tenet of TribalCrit is

> Theory and practice are connected in deep and explicit ways such that scholars must work towards social change [6, p. 430].

In this current project, we build upon two existing NSF-funded projects. The current project and the two prior projects illustrate this tenet: by developing materials for students to learn, they are creating a culturally responsive introduction to computing that creates a more welcoming invitation to study computer science. By leveraging our prior experiences, we provide an integrated and innovative technology experience for students and teachers.

The first project, based at Montana State University (MSU) and funded through NSF grant no. DRL 1657553, developed lesson plans that combine computer science content standards, IEFA Essential Understandings (EUs), and other (non-CS) Montana content standards by using storytelling [10–12]. This was achieved through the use of the drag-and-drop programming environment Alice, a programming environment that allows users to animate a virtual 3D world and made freely available by Carnegie Mellon University. Using Alice and custom made 3D models, students animate stories from Montana tribes that have been vetted by OPI, and use storytelling as a culturally responsive way to engage middle school American Indian and rural Montana students in learning computer science.

The second project, E-STITCH, was from Utah State University (USU) and was funded through NSF grant no. DRL 1758823. This project used e-textile technologies to develop innovative

technology experiences for elementary teachers and students, especially in rural areas, that are integrated with multiple content areas [15, 19, 23].

By bringing these two approaches together and aligning them with Montana's new CS standards, we envision the development of a new curriculum that is more robust in terms of CS, but also uniquely tailored to the stories and histories of Montana students and teachers. Together, the background of the team members situates them to address the unique challenges that arise in developing units for Montana students, and in developing support mechanisms for teachers to teach the units. The combined research and development team has faculty, a postdoc, undergraduate students, and graduate research assistants representing programs and degrees in Computer Science, Instructional Technology, Learning Science, Statistics, Statistics Education and Teacher Education. Moreover, they have experience collaborating with American Indian and rural communities in Montana and Utah.

2.2 Advisory Board

The advisory board (AB) comprises five members, including a representative from the Montana Office of Public Instruction (OPI) and from the American Indian Science and Engineering Society (AISES). The AB advises the project team on the pedagogical strategies and content utilized in the development of the curriculum, and will be providing iterative feedback on its design and development. As deployment of the curriculum approaches, the AB will also assess the planned implementation of our research instruments and protocols with an eye towards validity and reliability. The AB convenes twice per year via videoconference, and is available for email and telephone consultation between those meetings. The first AB meeting was held in Fall 2021. While much of the focus of this first advisory board meeting was to orient the AB members to the project, the AB feedback emphasized that the project team should strive to include American Indian knowledge and practices into every day of each unit. Moveover, a recent lawsuit[1] has re-emphasized the importance of soliciting feedback from the communities involved and the immediate need for more materials to be developed.

2.3 Master Teacher Panel

Curriculum materials will be reviewed by a master teacher panel (MTP) comprised of five elementary and middle school teachers (one per grade 4–8) selected for their experience and expertise in working with rural and American Indian students in Montana. Twice per year, the master teachers will engage in collective discussion akin to a focus group and will comment on perceived fit of the units to (non-CS) content standards, links to inquiry, and computational thinking opportunities for students. They will also discuss and make recommendations regarding perceived challenges for implementation (e.g., classroom logistics and time requirements, likely levels of students' prior knowledge, etc.) and pedagogical strategies that can enhance student success in completing the learning objectives for the lesson. To date, we have four teachers as confirmed members of the MTP and we have interviewed two of these teachers. Through these

[1] In Montana, American Indian education is mandated by the state constitution. In July 2021, the American Civil Liberties Union (ACLU) and Native American Rights Fund filed a class action complaint that the state is not meeting this constitutional obligation.

interviews, we have learned that our model (of teaching CS through storytelling) is a unique and engaging way to bring CS content into Montana classrooms.

3 A Sample Unit on Ledger Art

Like the two projects mentioned in Section 2.1, the current project is another illustration of the ninth tenet of TribalCrit. The main product resulting from this work is a unit that can be taught in classrooms grades four through eight, which will hopefully be an encouragement for American Indian and rural students to enter computing (the *practice*). The research—including the papers written and data collected—ultimately is done in support of the unit development and sharing how the unit was developed so other researchers and teachers can learn from our experiences (the *theory*). We describe the unit here, which is currently designed for grades four through six.

To address the current lack of CS courses and curriculum in Montana, we are developing curricular units that start at the primary education level and integrate CS content with Indian Education For All content as well as standards from English Language Arts, Math, and Science. Our units span four weeks (of four 50 minute classes per week), and consists of standards-based ideas and content from Montana encapsulated within two major projects, daily lesson plans, project guides, project rubrics, pedagogical-content recommendations, and space for teachers and students to interpret and align the unit resources to their own practice and style. For the teachers, we also provide technical guides to support teachers as they troubleshoot circuitry, crafting, and programming challenges that arise.

In this paper, we present an exemplar unit from our curriculum centered on ledger art. Long before the arrival of Europeans to the Americas, Plains Indians documented historical events and personal visions using petroglyphs and pictographs. Early European artists in what is now Montana introduced Western styles and tools to the American Indian people they met. Native artists incorporated these new styles and tools into their pictographic styles over time [1]. Ledger art is an art form that originated with the Plains tribes, who used ledger books (e.g., from trade or military) as paper for drawings or watercolor paintings that chronicled daily life, and was most popular during the 19th century, a time of great change for the Plains Tribes. The result was artwork superimposed over the historical records that chronicled daily life. Contemporary ledger artists use visual narrative as a way to document cultural heritage and comment on contemporary American Indian life [2].

The Ledger Art unit is aimed at educating and raising awareness of the histories and futures of American Indian cultures in Montana. In this unit, students create their own artwork inspired by the style of ledger art; see Figure 1. This unit is broken into five sections, as follows:

1. *Section 1: Ledger Art*. The teacher introduces the formation of reservations through treaties between the US Government and tribal nations. Students analyze historical and contemporary Montana ledger art through symbolism. Students begin to consider stories from their lives that they want to represent in the style of ledger art and consider the symbolic representations that they will use to convey a visual narrative. This section comprises two 50-minute lessons.

Figure 1: A sample project from the ledger art unit. This project tells a story using a visual narrative, supplemented by LEDs and sensors.

2. *Section 2: Circuits*. The teacher introduces simple, parallel, and series circuits so that students can add LEDs and computational functionality to their ledger art projects. Science concepts such as current, polarity, voltage, and conductors are explored. Students design a circuit on their ledger art projects using a microcontroller and LEDs to emphasize key symbolic representations of their visual narratives. This section comprises two 50-minute lessons.
3. *Section 3: Programming*. Students use pair programming techniques to code the LEDs on their ledger art projects and emphasize key elements of their visual narratives. The teacher introduces algorithms, functions, and debugging. Students use their ledger art inspired projects to share their stories. This section comprises four 50-minute lessons.
4. *Section 4: Encryption*. The teacher introduces encryption, and create a communication protocol that translates the letters of the alphabet to decimal and then to binary, and use that protocol to encode messages as another layer on their already functioning ledger art project. The teacher introduces nonverbal communication methods such as sign language used and nearly lost by Montana tribes. This section comprises four 50-minute lessons.
5. *Section 5: Storytelling*. Students revisit the formation of reservations by analyzing four treaties, uncovering another discussion on termination, relocation, and forced assimilation. The teacher introduces sensors, and students learn to collect data using the sound sensor on the microcontroller. Students discuss the diversity of data collected among users and the need for inclusive design when making new technologies. Students tell their stories to their peers, supplemented by the symbolic narratives of their ledger art projects. This section comprises three 50-minute lessons.

The purpose of our efforts is to integrate CS into Montana schools while also delivering content from the Indian Education for All Act (IEFA). IEFA presents seven essential understandings regarding Montana American Indians, and mandates that all educators in Montana, regardless of content area or grade level, must teach American Indian education to all students [22]. In addition, we chose English Language Arts as the primary content standard for this unit. As a whole, this unit addresses: CS content standards, IEFA EUs, and other content standards.

CS: Two of the Montana CS standards addressed in this unit are: "CS.AP.4.2 Students break down problems into smaller, manageable subproblems to facilitate the program

development process" and "CS.AP.4.3 Students test and debug a program or algorithm to ensure it runs as intended" [3].

IEFA: Essential Understanding 6 notes, "History is a story most often related through the subjective experience of the teller. With the inclusion of more and varied voices, histories are being rediscovered and revised. History told from American Indian perspectives frequently conflicts with the stories mainstream historians tell" [5]. There are connections to be made, even for primary level students, about why inclusion is an important part of technology development. Through constructions, dialog, collaborative work, and storytelling, we provide space for students to develop their own ideas of what computing is, and how computing fits in their lives while also honoring American Indian epistemologies of sociocentric, Earth-focused futures.

Other: The non-CS content standards addressed in this unit are the fourth through sixth grade English Language Arts (ELA) content standards, which are addressed by supporting student knowledge and practice of narrative writing. For example, "RL.5.5 Explain how a series of chapters, scenes, or stanzas fits together to provide the overall structure of a particular story, drama, or poem" [4] is included when students develop and analyze the narrative arc of stories.

In this unit, knowledge is constructed through meaningful, personalized, open-ended projects. Open-ended projects allow students to develop a personal relationship with the physical artifact they create [21]. We prioritize the ability for students to personalize their projects in deeply personal and meaningful ways by emphasizing student designs as a precursor activity upon which we situate future knowledge construction [16]. Focusing on learner identities within computing has been shown to promote a richer understanding of learning and teaching in CS education [20].

4 Discussion

The development of computer science standards in Montana opens new avenues for curriculum and program development across the state. Using this newfound momentum, we are developing curricular units that introduce computing using the stories and experiences from Montana Tribes. This paper presents initial stages of developing a culturally responsive curricula. We utilize a collaborative, community-based design processes to not only support student acquisition of computing content, but also to allow learners to construct non-traditional schema for what computing is and who computes as well as to increase awareness and education of the IEFA Essential Understandings.

As this is a continuing project with an iterative design process, the final unit may differ compared to the one presented above. But, it is our hope that the tenets upon which we build our curriculum design are applicable to others. In particular, the next round of input will involve piloting the unit in a classroom, where we can use student feedback and observations of student learning to improve the curriculum. In addition, we plan to extend the unit presented above to seventh and eigth grades (e.g., by expanding on the use and types of communication protocols).

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