Immersive Learning Research Network

Design of a Culturally Situated Hybrid Immersive and Hands-On STEM Learning Environment for Middle School Students on Navajo Nation

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Abstract. This extended abstract describes early-stage research on the research, design, and development of two culturally situated STEM curriculum units for Navajo Nation (Diné) middle school students, on the topics of energy and water, blending immersive and hands-on experiences. The first unit addresses the significant issue of energy access on Navajo Nation, where 32% of homes lack electricity. Culturally relevant, virtual experiences provide engaging and motiving narrative-based contexts for learning, aiming to inspire the next generation of Diné engineers and scientists to use their cultural and STEM knowledge to support their communities. We present the design of a prototype exploring options for solar energy on Navajo Nation, using immersive, place-based virtual representations, and feedback from teachers and students who engaged with the prototype. We describe the design of the full energy unit, and upcoming plans for classroom testing during spring, 2025. Initial findings from this classroom testing will be shared in the poster presentation of this extended abstract at the ILRN conference in June 2025.

Keywords: Science, Engineering, Middle School, Virtual, Culturally Relevant, Indigenous

1 Introduction

This extended abstract presents a description of the early-stage research on the development of two culturally-situated STEM curriculum units for Navajo Nation (Diné) middle school students, on the topics of energy and water. The curriculum units are being designed to alternate between virtual experiences and hands-on engineering activities. The web-based desktop Unity 3D immersive virtual experiences will provide situated, place-based investigation of energy and water on Navajo Nation, designed to build student awareness and understanding of the cultural and historical context of the topics, and to provide opportunities for students to explore the past, present, and future of energy and water in the Navajo Nation. The hands-on engineering design activities will support learning of science and engineering content and practices, culminating in an open-ended engineering activity to engage students in designing future-oriented solutions for challenges around energy and water on the Navajo Nation.

We hypothesize that this culturally-situated curriculum, blending immersive virtual experiences and hands-on engineering design, will be effective and engaging in supporting Diné middle school students. The proposed curriculum is being designed to promote understanding of the cultural context, science concepts, and engineering design, to engage students in exciting virtual and hands-on activities, to encourage students to use their unique cultural assets in design, and to increase awareness and interest in STEM learning and career pathways.

The project is still in the development phase; this abstract presents the design in progress for the full curriculum unit on energy, and an overview of a prototype energy activity. We include screenshots of virtual components, and description of testing and feedback from teachers and students who engaged with the prototype. We describe upcoming plans to test the full energy curriculum in classrooms during spring, 2025. Initial findings from this classroom testing will be shared in the poster presentation of this extended abstract at the ILRN conference in June 2025.

2 Theoretical Framework

2.1 Context: Energy on Navajo Nation

Energy access on Navajo Nation is a major issue. The Navajo Nation covers an area of roughly 71,000 km^2, including portions of Arizona, New Mexico, and Utah, and is the largest tribal reservation in the United States. In 2023, approximately 60,000 people on Navajo Nation (32% of the population) were living without electricity, according to the Navajo Tribal Utility Authority (NTUA) [1]. The land contains significant natural resources, including oil, uranium, and coal. There were several coal mines and powerplants on Navajo Nation that provided jobs and revenue to the Navajo people, but in recent years several mines and generating stations have closed. Their closure meant significant loss of jobs to the community, but also a transition away from coal's negative environmental and health impacts. The Navajo Nation land and climate is well-situated to shift to solar energy [2], and renewable energy sources are also recognized to be more in alignment with traditional beliefs about living in harmony with nature [3]. There is a need to empower Diné students to build a sustainable future for Navajo Nation with renewable energy.

2.2 Virtual Place-based Learning

Place-based learning promotes engagement in learning through local, authentic, meaningful problem-solving contexts [4]. It has been shown to increase learning, positively change perceptions of the importance of science, and increase students' self-efficacy and engagement in scientific practices [5]. Culturally situated learning, place-based teaching also has potential to attract underrepresented groups to science, through personally meaningful STEM learning aimed at addressing challenges in the students' local community [6, 7], providing learners a historical, cultural, and ecological perspective, and helping students see science as relevant to their lives [8, 9].

Virtual place-based experiences have been shown to demonstrate similar motivational and educational advantages [10], along with added opportunities to travel over space and time, and to engage with a place in ways not available in real life, e.g., to virtually transition between past, present, and projected futures [11].

Culturally relevant learning strives to make connections with students' cultural knowledge and experiences [12]. Immersive environments provide compelling platforms for building engaging and motiving, narrative-based contexts within which to embed curricular lessons, enhancing student motivation and learning. Culturally relevant, virtual experiences can authentically represent real-world problems that are relevant to both the curriculum and to students' interests, cultures, or lived experiences, linking to students' funds of knowledge and frames of reference, and enhancing student motivation and learning [13–16].

3 Methodology

3.1 Design Overview

The full Energy unit is intended to span three weeks of class time, including one week of place-based virtual environment activities, and two weeks of hands-on engineering projects. In four virtual experiences, students will explore the past and present of energy on the Navajo Nation. Each virtual experience will cover one approximately 30 minute class period, and "set the stage" for an associated hands-on engineering design activity during one or more following class periods, so that the curriculum alternates four times between virtual and hands-on experiences. The first three hands-on activities will involve closed-ended engineering knowledge and/or skill building activities around some aspect of energy on Navajo Nation; the fourth will be an open-ended Diné design project for students to prototype future solutions to address energy issues. The curriculum includes bridging through teacher-led classroom activities involving discussion, reflection, and connection with students' and their families' experiences and history with energy. Table 1 presents an overview of the planned unit.

The curriculum centers on Diné teachings which emphasize the interconnectedness between humans and nature, and the importance of preserving clean air, water and natural resources to meet the needs of future generations. The materials are being designed, tested, and revised collaboratively with input from Diné advisors, teachers, and community members, reflecting their lived experiences with respect to energy access, trends in energy usage, related science and engineering concepts, and cultural perspectives.

Understanding goals for the curriculum include (a) Understanding different sources of energy and their environmental, economic, and cultural/spiritual impacts; (b) STEM career options on Navajo Nation relating to energy, (c) Impacts and challenges of energy use on Navajo Nation; (d) STEM learning goals for science and engineering, and (e) Interconnectedness of culture, energy, science and engineering.

Table 1: Place-based virtual experiences and associated hands-on engineering activities

Virtual Experiences	Hands-On Engineering Activities
Historic: How people lived before electricity. Help a family prepare for winter. Building a hogan (home), gathering firewood, storing and preserving food.	Build a model hogan and measure insulation properties of different materials.
Coal: History of coal mining and power generation on Navajo Nation. Impacts – environmental, financial, spiritual, health. Virtual coal mine, power plant.	Build a model power plant to learn how they generate electricity.
Solar: Using the sun to generate electricity. Learn about on-grid solar arrays, and how to set up off-grid solar units. Talk to homeowners, line workers, installers.	Build circuits with solar panels, build a movable solar panel systems to track the light source.
Future: Moving towards energy sovereignty and a sustainable future, considering impacts on the land and the people, career opportunities in renewable energy.	Open-ended design project to prototype future solutions to address energy issues.

3.2 Immersive Experiences with 3D Virtual Environments

The virtual experiences are being developed using web-based desktop Unity 3D, and will run on web-accessible classroom laptop or Chromebook computers. Desktop 3D environments offer a cost-effective solution by leveraging existing computer infrastructure, minimizing the need for expensive hardware like VR headsets, and promoting greater accessibility, particularly important for schools like those on Navajo Nation with limited funds and resources. The project expects to reach middle school teachers and students in 15 or more schools across Navajo Nation, so using technologies already available is of key importance.

From an educational perspective, desktop 3D environments can also deliver highly effective immersive experiences [11, 17]. Some definitions of immersion in educational environments focus on spatial immersion [18], by which measure a 3D desktop system might be characterized as non-immersive. However, desktop 3D virtual environments have significant affordances for immersive experiences through powerful situated and experiential learning, a rich, realistic context, and a greater “sense of place” [11, 17, 19]. A broader perspective on dimensions of immersion [20] suggests that the immersive elements of desktop 3D environments might center not on perceptual and sensory immersion, but rather on features such as *narrative* immersion. Through narrative representation of locations and characters that represent personally meaningful and culturally relevant representations of real-world people, historical context, and current challenges, the experiences are likely to be intrinsically motivating and immersive for students.

Each virtual experience will begin as a Diné gathering in a hogan with a multi-generational family, with the player taking part as a young family member. The conversation turns to energy, and an elder relative starts to tell a story, which becomes a transition to the 3D interactive experience. A map represents virtual locations on Navajo Nation during the appropriate time period. Associated with each location are non-player characters (NPCs) that students can converse with, both in English and with audio also in the Navajo language. Students are given quests that involve helping the community with tasks associated with energy and the historic context.

3.3 Prototype

Design and development of the full curriculum is in progress. During the past year, a prototype immersive virtual activity was developed that focused on solar energy on Navajo Nation, the third virtual experience of the full unit. This experience begins with a map of Navajo Nation that shows different places to visit (Fig. 1). At first only the Grandparents’ home is visible and clickable. At this location, there is a home, a grandmother, and a dog. The player can click to talk with the grandmother, and through conversation learn that the home doesn’t have electricity, which causes several difficulties. The player offers to find out what the grandmother’s options are for getting electricity to her home (Fig. 2). This prototype experience includes placeholder dialog, 3D models, and UI elements, to be revised based on testing and feedback from Diné educators, students, and community members.

Fig. 1: Map of Navajo Nation with locations to visit

Fig. 2: Grandparents' Home

The experience includes visits to a home with a small-scale, off-grid solar installation, at which the player learns about the benefits and challenges of this solution (Fig. 3, left). The player also visits a home that has just been connected to the power grid through transmission lines. At this location, the player can also talk with line workers and learn about the challenges and the programs run by the Navajo Tribal Utility Authority (NTUA) to extend electricity lines to remote homes on Navajo Nation (Fig. 3, right). The player can follow the lines to an electrical substation, to learn about electricity generation at the power plant. They can also visit the Kayenta Solar Array, which opened in 2017, as an example of the future of Navajo Nation using large-scale solar power. Through these explorations and conversations with community residents and workers, the player gains the knowledge to be able to make a recommendation to the grandmother about options for access to electricity at her home.

Fig. 3: Conversation at the off-grid solar home, and with NTUA workers installing power lines.

Prototype hands-on activities follow from the virtual environment; students use the virtual environment to understand the context and explore lived experiences on the Navajo Nation that they may or may not have themselves, and then engage in two types of hands-on engineering activities related to those experiences.

- Closed-ended engineering knowledge and/or skill building activities in context. For the prototype, this involved learning about basic circuits and solar energy, using small solar panels and lamps, and connecting solar panels to power other devices.

- Open-ended design problems in context. For the prototype, student teams identify how they want to help the grandmother who they “met” at the beginning of the virtual environment scenario to use electricity to solve a problem, and then design and build a linear chain reaction machine involving solar panels as a functional prototype of the solution (e.g., to provide light via solar panels and LEDs).

3.4 Prototype Testing

In June 2024, the prototype activities were piloted at two STEAM summer camps in partner schools on the Navajo Nation; one in Arizona and one in New Mexico. Each 5-day full-day camp served approximately 25 Diné students in grades 6-9 and 2 science teachers from each school. The prototype activities were embedded in the larger STEAM camp context of engineering chain-reaction machines that tell stories. In July 2024 the prototype was tested with a third group of Diné students at a second location in Arizona.

Both the immersive virtual experience and the hands-on activities were well-received by students and teachers. Students found the virtual environment interesting and easy to use, and they enjoyed talking to non-player characters (NPCs), especially the grandmother and the energy workers. Students felt that the virtual locations seemed realistic and familiar, and liked having choices about questions to ask, and learning different points of view about how people face the problem of how to get electricity.

Feedback from students included requests to have more interactive features in the virtual environment, for example, some students wanted to drive the truck to town to get propane for grandma. Students wanted more places to explore, and to be able to go inside the house to see how energy is used, e.g., a wood stove. Some students recalled stories from their grandparents about growing up without electricity, and some were surprised to learn how many homes on Navajo Nation are still without electricity. Feedback on the hands-on curriculum included particular interest in working with solar panels. None of the students had ever worked with solar panels before, and they appreciated being able to generate electricity from the sun.

4 Next Steps

The complete curriculum, including four virtual immersive experiences for the energy unit (see Table 1 above) are currently in design and development, in collaboration with Diné educators and other community members. Detailed feedback received during the pilots is being used to inform revisions the prototype solar experience, as well as the rest of the curriculum.

The virtual experiences are being designed to include the following new features:

- A framing narrative in which the player is learning about energy at a multi-generational family gathering, with storytelling to the context and provides a transition to interactive visits to locations and events across time and distance.
- Options for voice narration in both English and Navajo.
- Video clips of real-world places and people within the virtual experience to provide additional realism and context, including video interviews with Diné workers describing their energy-related careers.
- Interactive challenges within the virtual world in which the player helps past and present Diné NPCs with in-game challenges. For example, helping an NPC set up a personal solar unit and connect it to their home to provide electricity for lighting and refrigeration.

The project intends to test the full three-week curriculum unit with up to 600 middle school students and 10 teachers across 5 schools during February-May 2025. This study will interview and survey teachers and students about their experiences with the hybrid learning environment, and the impacts of the unit on student learning of science and engineering content and practices and also on affective measures, such as engagement, self-efficacy, motivation to learn science, and interest in STEM-based careers.

Findings from the spring 2025 testing will be presented in the poster presentation of this extended abstract at ILRN 2025. Over the next two years, we will revise and complete the energy unit, and also develop and test a second unit representing challenges of water access and security on Navajo Nation.

5 Significance

This research will advance knowledge on the design of virtual 3D immersive learning environments blended with hands-on project-based learning in culturally situated contexts. The project aims to engage Diné (Navajo) middle school students in place-based virtual scientific investigations and hands-on physical experiments and engineering design. This curriculum has potential to inspire the next generation of Diné engineers and scientists to use their cultural and STEM knowledge to strengthen their communities and promote tribal sovereignty. This study focuses on a single large tribal community (the Diné), but the work provides a model for culturally situated immersive and hands-on STEM learning that could be adapted in other contexts as well.

Acknowledgements

This material is based upon work supported by the National Science Foundation under grant DRL-2241802. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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