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Designing Futures: Place-Based STEM Learning through Cultural and Spatial Innovation

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Abstract

This study examines how culturally grounded and immersive design pedagogies can enhance STEM engagement for Native American middle school students, integrating Place-Based Education (PBE), Culturally Relevant Teaching (CRT), and Problem-Based Learning (PBL). Utilizing Virtual and Augmented Reality (VR and AR) and 3D printing, the project aimed to boost student interest and engagement in STEM through culturally responsive, problem-solving modules. A Design-Based Research (DBR) methodology facilitated a co-design process with educators, community members, and students from three Oklahoma tribes (Citizen Potawatomie Nation, The Otoe-Missouria Tribe, and United Keetoowah Band of Cherokee Indians) to develop a curriculum incorporating local cultural narratives and environmental contexts. Findings show that place-based and culturally relevant pedagogies significantly enhance STEM education in tribal communities. Native educators effectively adapted the curriculum, integrating tribal origin stories and cultural practices into activities like architectural visualization and design thinking. Despite challenges such as irregular attendance and COVID-19 disruptions, the program successfully increased student engagement and motivation, particularly through hands-on hackathons. This research underscores the transformative potential of combining PBE, CRT, and PBL with advanced technologies to deepen students' connections to their heritage, enhance learning experiences, and strengthen STEM identities. Future plans include expanding professional development for educators and incorporating career narratives from Native American STEM professionals to further inspire students. Discussing these topics through the tangible contexts of architecture and interior design makes abstract ideas more engaging and accessible for students. As researchers committed to inclusive and community-centered educational design, our engagement with the three partner Tribal Nations stems from a longstanding collaborative relationship grounded in mutual respect. This partnership is guided by reciprocal learning, with communities benefiting through access to emerging technologies, tailored curriculum, and STEM enrichment for their youth. This study highlights the importance of culturally responsive, place-based STEM education in preparing Native American students for future STEM careers.

Keywords

Culturally Relevant Teaching, Native American, Place-Based Education, STEM Education, Virtual and Augmented Reality

Introduction

Place-Based Education (PBE) is an instructional approach that emphasizes the concept of place to create authentic, meaningful, and engaging personalized learning experiences for students. When combined with Culturally Relevant Teaching (CRT), which integrates students' cultural

references into all aspects of learning, it has the potential to enhance educational outcomes. This study aimed to explore whether integrating these two frameworks with Problem-Based Learning (PBL) to solve spatial design problems using technologies such as Virtual and Augmented Reality can improve students' interest in STEM education.

A project was developed that focused on an after-school program designed to increase STEM career interests and motivations among Native American middle-school students. Utilizing VR, AR, and 3D printing, students solved spatial design problems through culturally responsive, problem-based learning modules. A generative co-design process involving educators, community members, and students incorporated historical and contemporary cultural knowledge, targeting middle-school students and educators from three tribes in Oklahoma. The project established technology centers in the tribes, an inclusive curriculum, and community-defined hackathons. Research focused on the program's impacts on STEM career development, using mixed methods to evaluate student interest, motivation, and STEM identity. Findings and resources were made available online, contributing to the knowledge base on culturally responsive programs. The study employed a Design Based Research (DBR) Methodology aimed at improving educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in the real-world setting. The purpose of this study is to examine how the integration of Place-Based Education, Culturally Relevant Teaching, and Problem-Based Learning, supported by immersive technologies such as VR, AR, and 3D printing can enhance STEM engagement, cultural identity, and design thinking among Native American middle school students. The study shares findings from a multi-year, co-designed afterschool program conducted with three Tribal Nations in Oklahoma.

Literature Review

Place based education and Design pedagogy

Place-based education (PBE), also known as place-based learning, is an instructional approach that capitalizes on geography to create authentic, meaningful, and engaging personalized learning for students (Sobel, 2004). It hinges on the concept of using the local community and environment as a starting point to teach concepts in various disciplines, including language arts, mathematics, social studies, science, and more (Smith, 2002). The principles of PBE are founded on the belief that learning becomes profoundly relevant to students when it is concretely grounded in their own local experience, culture, landscape, and tradition (Gruenewald & Smith, 2008). This approach encourages exploration and connection to the local place, thereby fostering a sense of stewardship and attachment towards it (Theobald, 2004). The concept of place-based education holds substantial relevance in architectural and interior design. As architecture and interior design are disciplines deeply rooted in the physical and cultural context of places, PBE can enhance understanding and respect for the community's unique aspects and its relationship with the environment (Ardoin et al., 2019).

A place-based approach to design allows architects and designers to learn about the history, culture, social norms, and geographical features of a place, which can significantly influence their designs. For instance, the understanding of local materials, construction methods, climate, and cultural preferences can drive the selection of design strategies, materials, and technologies that are relevant, sustainable, and resonant with the local community (Lane & Johnsson, 2019). Furthermore, PBE is integral to understanding the physical and social

characteristics of a place, contributing to the design of spaces that contribute positively to users' wellbeing and experiences (Vanclay et al., 2015). By understanding the nuances of a place, architects and designers can create structures and interiors that promote a sense of belonging, support cultural continuity, and enhance the lived experience.

Therefore, Place-based education can facilitate a more nuanced and engaged understanding of the local environment in architectural and interior design education, highlighting the cultural, historical, and physical aspects of a location and translating that understanding into designs that honor, reflect, and enhance the uniqueness of the place.

Culturally Relevant Teaching (CRT) and Culturally Relevant Design

Culturally relevant teaching, also known as culturally responsive teaching, is a pedagogical framework that integrates students' cultural references into all aspects of learning. It aims to make learning more relevant and effective for students by respecting and honoring their cultural backgrounds and experiences (Ladson-Billings, 1995).

In Language Arts and Literature, culturally relevant teaching suggests using texts and materials that reflect the cultural backgrounds of students. Teachers can integrate diverse authors and stories into the curriculum, enabling students to see themselves and their experiences represented in what they read and study (Lee, 2007). In Mathematics and Science, culturally relevant teaching implies incorporating real-world problems relevant to students' cultures or using culturally based examples to explain abstract concepts (Aguirre et al., 2013). For instance, a math teacher might use textile patterns from a community's cultural heritage to teach geometry, or an environmental science teacher might explore local environmental issues pertinent to the community (Leonard et al., 2010).

In Social Studies and History, culturally relevant teaching involves teaching history and social issues from various perspectives, including those of marginalized or underrepresented groups. It includes incorporating local and indigenous histories and allowing students to examine events from multiple viewpoints (Epstein, 2009). In Arts and Music, culturally relevant teaching encourages the exploration and appreciation of art forms from various cultures, particularly those represented in the classroom. It includes exploring diverse musical traditions, art styles, and cultural expressions, thereby validating students' cultural experiences and identities (Banks, 2019). Moreover, culturally relevant teaching is not limited to subject matter. It also pertains to teaching strategies, classroom dynamics, and assessment methods. It promotes cooperative learning strategies that align with communal cultures and includes assessments that value diverse ways of demonstrating knowledge and skills (Gay, 2018). Culturally relevant design (CRD) plays a critical role in the field of architecture and interior design. This approach emphasizes the importance of integrating cultural contexts and understanding into design processes and outcomes, enabling designs to reflect, respect, and honor the cultural backgrounds and experiences of the community (Banerjee & Loukaitou-Sideris, 2011).

CRD goes beyond the aesthetics of a design to incorporate meaningful elements of culture and tradition, facilitating a deeper connection between the people and the built environment (Champagne, 2015). It aims to create spaces that are not just functional but also culturally meaningful and comfortable. These designs often reflect the history, values, traditions, and lifestyle of the local community, thus forming a sense of cultural continuity (Tunstall, 2013). In architecture and interior design, CRD could involve incorporating traditional building materials

and techniques, integrating cultural symbols and motifs, or designing spaces that reflect cultural practices and norms (Crysler et al., 2012). For instance, in a community with a history of textile production, designers might integrate textile patterns into the design elements of a building, or in a community with specific social gathering traditions, designers might create spaces that support these social activities (Tunstall, 2013). CRD also supports sustainability as it tends to be sensitive to local environments, using locally sourced materials and responding to local climate and ecological conditions. It acknowledges the deep connection many cultures have with their natural environment and seeks to maintain and strengthen this connection through design (Banerjee & Loukaitou-Sideris, 2011). Furthermore, CRD plays a significant role in design education. Incorporating culturally relevant perspectives into design education encourages students to respect and learn from diverse cultural knowledge systems and prepares them to design in a culturally responsive manner

Culturally Relevant Teaching and Culturally Relevant Design share a foundational principle: to honor, respect, and integrate the cultural backgrounds and experiences of the community into teaching and design practices (Ladson-Billings, 1995; Banerjee & Loukaitou-Sideris, 2011). CRT, in the pedagogical context, aims to make learning more relevant and effective by drawing on students' cultural knowledge and experiences (Ladson-Billings, 1995). Similarly, CRD in the context of architecture and interior design, aims to make designs more meaningful, functional, and comfortable for the community by incorporating cultural context and understanding (Champagne, 2015). Both CRT and CRD value the knowledge systems embodied within local cultures. CRT integrates these knowledge systems into pedagogy, acknowledging and validating them as a crucial part of the learning process (Aguirre et al., 2013). CRD, on the other hand, utilizes these knowledge systems in creating designs that reflect and honor the cultural practices, norms, and aesthetics of the community (Tunstall, 2013). Both CRT and CRD also share a commitment to fostering a sense of belonging and identity affirmation. CRT achieves this through creating an inclusive learning environment that validates students' cultural identities (Gay, 2018). Similarly, CRD creates spaces that reflect and affirm the cultural identity of the community, fostering a sense of cultural continuity and belonging (Crysler et al., 2012).

PBE and Culturally Relevant Design (CRD)

Place-Based Education (PBE) is a powerful pedagogical tool that can be particularly effective when applied to architectural and design contexts involving indigenous communities. Its emphasis on local knowledge and cultural sensitivity makes it an ideal approach for designing spaces that respect, reflect, and honor Native American cultures and environments (Demmert & Towner, 2003). Space provides a useful metaphor for teaching about culture and technology in STEM fields like design. Culturally relevant design is a critical aspect of architectural and interior design, especially in regions inhabited by indigenous populations. Since everyone experiences existing in physical spaces, using the concept of space allows students to better relate to and understand cultural influences and technological applications. Discussing these topics through the tangible contexts of architecture and interior design makes the abstract ideas more engaging and accessible for students. For Native American communities, the local environment, customs, history, and values have long been the basis of their architectural practices (Champagne, 2015). A place-based approach can help architects and designers grasp these intricate nuances, enabling them to create designs that not only meet functional needs but also resonate deeply with the community's cultural and spiritual sensibilities (Ardoin et al., 2019). The designs derived from this approach can be highly contextual, reflecting aspects such

as local climate, available materials, traditional building methods, and cultural symbols and motifs. These designs are more likely to be sustainable, as they respect the ecological boundaries of the place, and culturally relevant, as they echo the community's heritage and values (Banerjee & Loukaitou-Sideris, 2011).

Culturally relevant design and Place-Based Education (PBE) share a conceptual similarity with Christopher Norberg-Schulz's idea of 'Genius Loci' or 'Spirit of Place.' Genius Loci, a term originating from Roman mythology, was revitalized by Norberg-Schulz in the context of architecture to express the unique, unrepeatable character of a place (Norberg-Schulz, 1980). Similar to PBE and culturally relevant design, the Genius Loci concept involves deeply understanding and appreciating the essence of a place – its history, culture, environment, and community – and reflects these aspects in architectural design. This is strikingly akin to the principles of culturally relevant design and PBE, which hinge on the meaningful integration of local community, culture, and environment into the learning process and design practices (Ardoin et al., 2019; Sobel, 2004).

Norberg-Schulz (1980) emphasized the importance of understanding a place in its totality – including its topography, climate, light, and tectonics – to capture its unique 'spirit.' This approach requires an understanding not just of physical characteristics but also the cultural and historical context of the location. Similarly, culturally relevant design adopts this contextual understanding, aiming to create designs that respect and reflect the local culture and community (Lane & Johnsson, 2019). PBE and the idea of Genius Loci both advocate for a sense of rootedness and a deeper connection to the place. PBE supports this through the educational process, promoting the exploration of local environments and cultural practices (Smith, 2002). In parallel, the Genius Loci approach in architectural design aims to evoke this sense of connection through built structures that embody the spirit of the place.

Moreover, both approaches value the unique knowledge systems embodied within local cultures. Norberg-Schulz's concept appreciates the indigenous understanding of place and its embodied experiences, while PBE promotes the integration of indigenous knowledge systems into pedagogy (Bang et al., 2014).

PBE and STEM education in Native communities

Place-Based Education (PBE) and culturally relevant learning are pivotal pedagogical strategies that can greatly enhance STEM (Science, Technology, Engineering, and Mathematics) education. PBE, with its emphasis on contextual learning rooted in the local environment and community, provides a tangible and relatable way to introduce complex STEM concepts (Smith, 2002). By utilizing local resources and issues, PBE transforms the abstract ideas often encountered in STEM into concrete examples that students can experience and investigate firsthand (Sobel, 2004). For instance, students can study local water quality to understand concepts in chemistry and environmental science or analyze the structure of a nearby bridge to learn about physics and engineering principles.

Culturally relevant learning, on the other hand, adds another layer to the effectiveness of STEM education. This approach recognizes and incorporates students' cultural knowledge and experiences into teaching and learning processes (Ladson-Billings, 1995). This inclusion of students' culture can enhance the understanding and relevance of STEM concepts. For instance, in a community with a rich history of textile production, a math teacher might teach

geometry through the lens of textile patterns. This not only contextualizes mathematical concepts but also validates and integrates the community's cultural knowledge into the STEM classroom, fostering a greater sense of relevance and engagement among students (Aguirre et al., 2013).

Moreover, culturally relevant pedagogy in STEM also acknowledges the various ways in which different cultures engage with and understand STEM concepts. This can help to break down monolithic understandings of STEM and introduce students to a broader, more inclusive perspective (Bang et al., 2014). PBE has shown considerable potential in helping Native American students understand STEM (Science, Technology, Engineering, and Mathematics) concepts. Given the cultural significance of place in these communities, contextualizing STEM education within the local environment can help make these subjects more relatable, relevant, and engaging (Aikenhead, 2006). For example, studying local ecosystems or traditional building techniques can facilitate a deeper understanding of scientific concepts or engineering principles. Furthermore, this approach can promote a greater appreciation and application of indigenous knowledge systems within STEM, offering students a unique and culturally relevant perspective (Bang et al., 2014). This study aligns with calls from Indigenous scholars to center cultural identity and challenge systemic inequities in education (Nganga & Kambutu, 2024; Castagno & Brayboy, 2008). Hyscher's (2024) work on culturally relevant virtual environments further illustrates how spatial design can foster Indigenous language learning, resonating with the approach in our modules.

Taken together, the literature highlights the educational potential of integrating culturally responsive pedagogy, place-based learning, and immersive technology. However, few studies have examined how these approaches intersect in the context of Indigenous design education, particularly through co-designed spatial problem-solving modules for youth. This study responds to that gap by combining PBE, CRT, and PBL within a Design-Based Research framework to explore how immersive design tools (e.g., VR/AR/3D printing) can support STEM engagement among Native American middle school students. By centering tribal narratives and community co-design, this research contributes a culturally grounded model that expands the boundaries of traditional STEM education.

Method

We employed a Design-Based Research (DBR) methodology, following an iterative process of design, implementation, research/evidence, feedback, and adjustment of program components. This approach aligns with Design-Based Research frameworks as described by Wang and Hannafin (2005) and Barab and Squire (2004), which emphasize iterative refinement through practitioner-researcher collaboration in real-world settings. This approach aimed to improve educational practices through collaboration among researchers and practitioners in real-world settings, leading to contextually-sensitive design principles and theories. DBR involves multiple iterations and evaluations, relying on prior research and theory while contributing to the development of teaching and learning theories and producing instructional tools that withstand everyday practice challenges.

The project staggered the participation of each Tribal Nation afterschool program over four years to enable the team to learn and improve the Project-Based Learning (PBL) modules and generative design process. Each program's participation began with a professional learning

experience for afterschool educators in the summer prior to implementation. Afterschool educators and tribal elders collaborated to co-design culturally reflective modules specific to their Tribal Nation. Our project team coordinated the initial implementation of the program in the fall at each respective afterschool facility, followed by virtual support for the educators in the spring. This incremental training and support process was designed to prepare afterschool educators to implement the activities independently in subsequent years.

Over the course of the project, we hosted three summer workshops for afterschool educators at our home institution and sponsored 15 semester sessions of afterschool programs across three locations. Technology centers were established at each location to support the afterschool programs and mini hackathons. The afterschool program curriculum was made publicly available on the project website, including examples of digital cultural artifacts developed by the students.

The professional learning experience for afterschool educators included technical training on VR/AR technologies and curriculum, and collaboration to develop culturally explicit lesson plans. Each Tribal Nation nominated five individuals for a three-day summer workshop at our home institution. This workshop included training on software and curriculum modules, and collaboration with Tribal Nation educators to introduce culturally relevant themes and develop hackathon challenges. These workshops also facilitated meetings with current Native American undergraduates majoring in STEM fields to discuss college readiness and STEM career awareness from a near-peer perspective. Near-peer connections, where individuals learn from peers who are slightly more advanced in their knowledge or skills, are considered vital in educational settings. These connections foster a more relatable and less intimidating learning environment, as near-peers often share similar experiences and challenges with the learners. This can enhance motivation, engagement, and the overall learning experience (Authors, 2024)

For the afterschool STEM programs, the curriculum included seven modules targeted at middle school students aged 10-15. The project team coordinated the first semester implementation, with afterschool educators co-leading and participating in all sessions. In the following semester, afterschool educators led the program with the research team’s support. In subsequent semesters, the educators independently implemented the STEM program. In the final semester, teams of two educators and six students from each afterschool program were invited to the home institution to participate in a competitive hackathon as the project's finale.

All research involving minors was reviewed and approved by the Oklahoma State University Institutional Review Board (IRB). Informed consent was obtained from parents or guardians, and assent was secured from participating students, in coordination with tribal education departments to ensure cultural and procedural alignment. Tribal approval was also obtained through the respective tribal ethics committees and leadership of the tribes.

Developing Modules

The project used Problem-Based Learning (PBL) to encourage critical thinking, creative reasoning, and communication skills through innovative technologies such as VR, AR, and 3D printing. The curriculum included seven modules designed to help students learn problem-solving skills and retain information. Each afterschool program met once every two weeks for seven sessions during each fall and spring semester. Each week, students were introduced to a

new module that was built on the previously completed one. The modules were designed to be hands-on experiences using examples of architecture and interior design situated in the local environment and community. The PBL format allowed the challenges to change each year by introducing different problems or incorporating specific Tribal Nation interests and concerns. The project leadership actively involved Native American afterschool educators and Tribal Nation elders and leaders in developing the cultural connections and problem areas, through both formal and informal consultations during summer workshops, afterschool programs, and annual hack-a-thon meetings.

The co-design of the curriculum modules supported the goal of making the curriculum relevant and unique to each Tribal Nation while also being replicable for other Tribal Nation afterschool programs. These educational resources served as a starting point for afterschool educators and students to explore traditional homes and spatial design in architecture specific to their Tribal Nation. Afterschool educators and project consultants identified age-appropriate, student-centered explorations of related concepts, such as structural materials, artwork, and community activities, to strengthen student cultural identity and inspire architectural visualizations. Tribal Nation elders were consulted in deciding the design problems and annual hackathon challenges.

The curriculum included experiential learning modules that began with cultural learning and then provided an immersive technology experience. Each module aimed to explore a different facet of indigenous culture through spatial design, allowing students to develop technological skills through PBL. Each module included an immersive (VR or AR) example tailored to the specific Tribal Nation. These immersive examples were developed to capture and present the genius loci of indigenous spatial structures, allowing students to experience and deconstruct these concepts before reconstructing them as novel spatial experiences.

Module 01: Basic Building Blocks: Sketching to Rendering – This module focuses on developing students' spatial reasoning skills through visualization. It introduces them to the fundamentals of architectural visualization, including the basics of sketching and architectural drafting. Using place-based learning, students draw inspiration from their local environment and community structures, learning to translate these familiar elements into visual representations. Culturally relevant pedagogy is integrated as students incorporate traditional Native American architectural elements and symbols into their sketches, fostering a connection to their heritage. This foundational knowledge sets the stage for more advanced design work in subsequent modules, providing students with essential skills for architectural and design projects.

Module 02: Virtuality: Using VR in Architectural Visualizations – This module introduces students to the exciting world of content creation through 3D modeling software and the use of VR as a powerful design tool (Figure 1 c). By designing their own dorm rooms, students tackle real-world design challenges that are relatable and relevant to their future educational experiences. This exercise also serves to instill the idea of college life and underscore the importance of higher education as a significant part of their future. Through this project, students incorporate culturally relevant designs and motifs from their Tribal Nation into their dorm room models, celebrating their cultural identity while learning technical skills. By visualizing their designs in a virtual reality environment, students gain a deeper understanding

of architectural visualization and the parallelism between the design process and the scientific method.

Module 03: Virtual Realization: Modeling and Viewing a Building in VR – In this module, students create a virtual museum featuring their work. They begin by visiting and documenting a significant building in their Tribal Nation, such as a historical site or a culturally important structure. Using place-based learning, students gather data through 3D scanning, photography, and measurements to model the building in 3D software. The virtually recreated space serves as an interactive museum where students display their projects, enhancing their spatial thinking and technical skills. This module fosters a deeper connection to their cultural heritage by preserving and showcasing it in a modern, digital format, allowing students to contribute their work to a shared, immersive cultural resource.

Module 04: Virtuality to Physicality: 3D Printing – In this module, students transform virtual artifacts into tangible products using 3D printing, solving design problems through collaborative, team-based exercises. The focus of this exercise is on designing a light fixture (Figure 1 a). Students are introduced to the fundamentals of electricity and various types of lighting. They incorporate cultural elements into their light fixture designs, blending technical skills with cultural heritage. Place-based learning is emphasized as students draw inspiration from traditional Native American designs and motifs, creating meaningful, culturally inspired artifacts. This hands-on module not only teaches the technical aspects of 3D printing and electrical design but also encourages students to celebrate and integrate their cultural identity into their work.

Module 05: Empathic Design Process: Designing for Special Groups – This module introduces students to the concept of empathic design, emphasizing the Native American tradition of respecting elders. Students use an aging simulation suit (GERontologic Test suit) to experience the physical challenges faced by older adults, enabling them to develop thoughtful and practical design solutions. Place-based learning is incorporated as students consider the specific needs and cultural practices of their Tribal Nation's elders (Figure 1 b). Culturally relevant pedagogy is integrated as students design solutions that reflect traditional values of respect and care for elders, enhancing their ability to create innovative designs that improve accessibility and quality of life within their community.

Module 06: Augmented Living: Using AR in Design – This module challenges students to develop and enhance an everyday object using 3D modeling, with the final design presented through augmented reality (AR). Emphasizing anthropometric and ergonomic measurements, students learn to create designs that are both functional and user-friendly. Place-based learning is incorporated as students consider the specific needs and daily practices within their Tribal Nation. Culturally relevant pedagogy is integrated as students incorporate traditional designs and ergonomic considerations that reflect their cultural heritage, ensuring the objects they create are optimized for comfort, efficiency, and usability while honoring their traditions.

Module 07: VR+AR Mini-Hackathon – This team-based event tasked students with addressing a real-world issue within their Tribal Nation by utilizing the VR and AR technologies introduced in the preceding modules. These challenges were developed collaboratively with afterschool educators and tribal leaders, ensuring the projects were relevant and meaningful to the community. Emphasizing place-based learning, students engaged in projects that directly

impacted their local environment and community. Culturally relevant pedagogy was integrated as students applied their technical skills to solve problems that reflected their cultural values and priorities, fostering innovation and collaborative problem-solving in a dynamic, high-energy setting. Additionally, tribal elders were invited to participate and work alongside the students, enriching the experience with their wisdom and cultural insights.

Fig 1. (a) 3D printed light fixture, (b) GERT Suite and Wheelchair use with VR, (c) A student using VR

Codesigning the Modules

While the initial framework for the modules was developed by researchers, the true strength of the curriculum lies in its co-design process. This collaborative approach involves working closely with educators and tribal leaders to ensure each module meets the specific needs of the students and the community. This collaborative process was conducted during the teacher workshops in the summer. According to Wang and Hannafin (2005), Design-Based Research (DBR) involves iterative analysis, design, development, and implementation, which is critical in creating contextually sensitive educational practices. This process often entails deconstructing and reconstructing entire modules to tailor them to local priorities and cultural contexts.

For some tribes, the modules are infused with unique cultural stories that serve as foundational themes, enriching the learning experience and helping students connect more deeply with the material. This integration of cultural narratives aligns with culturally relevant pedagogy, which Gay (2018) describes as teaching that uses the cultural knowledge, prior experiences, and performance styles of diverse students to make learning more appropriate and effective. In other cases, the modules are adapted to address specific requirements or goals identified by the tribe, ensuring the content supports the tribe's broader educational and cultural objectives.

By prioritizing the co-design process, we ensure the curriculum is responsive and respectful to the diverse cultural landscapes of each Tribal Nation. This method fosters a sense of ownership among educators and students, making the learning experience more meaningful and effective. The collaboration between researchers, educators, and tribal leaders exemplifies a

commitment to culturally relevant pedagogy and place-based learning, ultimately enhancing the educational outcomes for tribal students.

The following overarching research questions aimed to capture in qualitative terms the impact of a technology rich and culturally immersive environment on students' generative knowledge in terms of culture and career:

RQ1: How do afterschool educators access and use the spaces, practices, and resources for culturally relevant teaching and learning (i.e. technology center, curriculum, and website)?

RQ2: In what ways do blended cultural learning and technology-rich immersive experiences support students' abilities to translate Indigenous concepts into creative design experiences?

RQ3: How does visual storytelling impact participants' personal, social, and cultural worldviews in relation to their STEM education and career interests?

Findings

Our research focused on three key questions related to place-based learning, culturally relevant pedagogy, and the impact of visual storytelling on STEM education and career interests in tribal afterschool settings.

Educator Use of Cultural and Technological Resources: For our first research question, we aimed to understand how afterschool educators accessed and utilized spaces, practices, and resources for culturally relevant teaching and learning. In the first year, we assessed the STEM capacity and instructional comfort of educators through surveys, interviews, and planning meetings. We collaborated with tribal educators to enhance the afterschool computing space, introduce problem-based learning (PBL), and integrate cultural resources and tribal origin stories. This initial assessment revealed varied levels of experience and commitment to STEM education across the three partner tribal nations. In subsequent years, the implementation of the curriculum faced challenges due to irregular student attendance and program disruptions caused by COVID-19. However, we adapted to these changes and successfully implemented the curriculum. Native educators played a crucial role in integrating VR technologies, enhancing cultural learning through emerging technologies. Embracing 'kid-culture' and providing hands-on learning opportunities proved essential for student engagement. Moving forward, we planned to involve more educators in professional development and coordinate with the afterschool program to recruit a larger number of student participants.

Educators particularly valued the hands-on nature of the modules and the integration of tribal narratives. One participant noted that "students were more engaged when stories from our own community were part of the lesson." The ability to use VR tools and cultural content together made the sessions more relevant and sustainable for long-term use.

Translation of Indigenous Knowledge through Immersive Design: For our second research question, we explored how blended cultural learning and technology-rich immersive experiences supported students in translating Indigenous concepts into creative design experiences. We introduced generative design and culturally relevant pedagogy to afterschool educators and student researchers through an intertribal educator workshop. This workshop used space as a cultural metaphor, providing an opportunity to model generative design and

explore pre-colonized societies. Involving elders, families, and cultural experts in design experiences was crucial for fostering intergenerational cultural exchange. The program revealed the need for curriculum modifications to create a fun environment with rewards for participation. Students engaged in activities such as scanning beadwork into a virtual museum and redesigning afterschool spaces during a hackathon. The creation of 3D objects was a significant motivator and confidence builder for students. Future iterations of the program were to focus on identifying cultural knowledge bearers and community-based problems, structuring the program into advanced and beginner groups, and providing resources for home use.

Students frequently incorporated elements like beadwork, traditional dwellings, and personal stories into their spatial designs. The act of scanning and transforming cultural artifacts into interactive digital forms not only increased confidence but also reinforced identity. One afterschool educator shared, “They saw their designs in 3D and said, ‘This is who we are.’”

Visual Storytelling and STEM Identity Development: For our third research question, we investigated how visual storytelling impacted students' personal, social, and cultural worldviews concerning their STEM education and career interests. The hackathon encouraged students to think critically and creatively about redesigning afterschool STEM program spaces, incorporating factors like space utilization, accessibility, and usability. Virtual and augmented reality technologies allowed students to explore emerging technologies and their practical applications in design and engineering. Empathic design principles taught students a human-centered approach to problem-solving. We faced challenges in collecting pre-post data due to varied student attendance and the impact of COVID-19. Moving forward, we planned to include video introductions by Native American STEM professionals and a career narrative activity to inspire students to think about jobs and careers. Revising the curriculum to include direct career connections and affective components would help develop STEM identity and emphasize the role of STEM-educated youth in addressing issues important to tribal nations.

Hackathon reflections revealed that visual storytelling helped students connect STEM activities to real-life cultural narratives. Students spoke about presenting projects to family members and elders, indicating an expanded sense of audience. This public-sharing context helped foster deeper meaning and long-term motivation to pursue STEM paths.

Summary

Overall, our research highlighted the importance of place-based learning and culturally relevant pedagogy in enhancing STEM education and career interests among tribal students. The transformative potential of technology-rich learning environments and the value of visual storytelling were crucial components in this educational approach.

Conclusion

This study aimed to explore the integration of Place-Based Education (PBE), Culturally Relevant Teaching (CRT), and Problem-Based Learning (PBL) to enhance STEM education for Native American middle school students. By utilizing technologies such as Virtual and Augmented Reality (VR and AR), as well as 3D printing, the project sought to improve students' interest in STEM education through culturally responsive, problem-solving modules.

Our findings underscore the importance of co-designing educational modules with input from educators, community members, and students to ensure the curriculum is culturally relevant and responsive to local needs. The iterative Design-Based Research (DBR) methodology facilitated continuous refinement of the program, enhancing its effectiveness and contextual sensitivity. By integrating cultural narratives and leveraging local environments, the modules fostered a deeper connection between students and their heritage, making learning more engaging and meaningful. The study revealed that incorporating place-based and culturally relevant pedagogies significantly benefits STEM education in tribal communities. Native educators played a crucial role in adapting and delivering the curriculum, which included problem-based learning activities that integrated tribal origin stories and cultural practices. This approach not only increased student engagement but also helped develop essential skills in architectural visualization, 3D modeling, and design thinking. Despite challenges such as irregular attendance and COVID-19 disruptions, the program successfully implemented its modules, demonstrating the potential of combining PBE, CRT, and PBL with advanced technologies to create a transformative educational experience. The hackathons and other hands-on activities proved particularly effective in motivating students and building their confidence in STEM subjects.

Moving forward, the project will continue to evolve, with plans to involve more educators in professional development and expand student participation. Emphasizing career connections and incorporating video narratives from Native American STEM professionals will further inspire students and strengthen their STEM identity. This study highlights the transformative potential of a culturally responsive, place-based approach to STEM education, supported by innovative technologies. By honoring and integrating the cultural heritage of Native American students, educators can create more relevant, engaging, and effective learning experiences that foster a sense of identity and belonging, while also preparing students for future STEM careers.

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